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DISCOVERY

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The Progress of Science

Consumer Research

For some centuries our social organisation has been centred on the producer; the consumer has been given a mere peripheral position, as a necessary 'sink' into which the goods produced can be poured. The assumption has been that if production and distribution are done for profit, and if the consumer is free to buy or refuse to buy anything on the market, then the 'law of supply and demand' will ensure that the consumer does eventually get what he needs. As a by-product of this assumption, science has been widely applied in production—in creating new products or improving the means of producing old ones.

The fact that our social machine has somehow or other worked shows that there is some truth in the assumption. But the increasing friction and repeated partial breakdowns of the machine in recent times shows that this survival-of-the-fittest method of industrial evolution is too slow to provide the ideal commodities in a modern world. The agriculturalist has long since ceased to depend on the natural laws discovered by Darwin to give him better plants and animals, and has preferred to plan their evolution through artificial breeding. In the same way it is becoming obsolete to depend on the, perhaps not so natural, laws of Adam Smith to improve commodities in general; there is need instead for the application of scientific methods to determine directly the needs of the consumer and the best ways of satisfying them. This application has now come to be known as 'consumer research'.

As in so many other things, the more rational organisation which the necessities of the last war forced upon us produced the first important steps towards useful consumer research in this country. The work of War-time Social Survey (an account of its activities appeared in Discovery, April 1944, pages 248–51) became the basis for planning the production and distribution of several types of goods and services. And operational research, which may be roughly described as consumer research with the fighting man as consumer, enormously improved the technique available in this field.

These remarks are prompted by the chapter on consumer research in *Science and the Nation*, a book written by members of the Association of Scientific Workers (Pelican Books, 1947; 1*s*.). Among the various possible applications of consumer research, this book gives most emphasis to the setting-up of standard specifications after careful survey of requirements. It is also stressed that these standards would have to be maintained by an extension of the inspection and control methods that are now used in connexion with food and drugs. Similarly, consumer research could be used to examine claims made in advertisements. In the U.S.A. that function is carried out by voluntary organisations which publicly announce the results of their investigations; but our libel law would prevent the application of that method here, and the work could only be done by some organisation free from that restriction.

The book makes three main organisational suggestions. The usefulness of Social Survey (the post-war continuation of War-time Social Survey) could be greatly increased if its findings were regularly published, instead of being kept for the confidential information of ministers and departments, as is usual at present. It is granted that there may at times be reasons why the recommendations of the Survey should not be carried out; but the public should be given the chance to judge both the recommendations and the counter reasons. The second suggestion is that the Co-operative Movement, since it combines producer, distributor and consumer, should undertake consumer research.

The third suggestion is a much bigger one—the setting-up of a Consumer Research Council, on similar lines to the Medical Research Council, and with a suitable research organisation to back it. It would work in close liaison with other Government departments which are concerned with the consumer. It would report on quality, performance and relative price of consumer foods; but in the event of failure to conform to standard, legal action would be left to the appropriate Government department. It would make surveys and studies on which recommendations for future productions and distribution policy could be based. And, to make them fully effective, its findings would be widely publicised.

We have concentrated on this one chapter of the book in order to show that it discusses the future of British science in a concrete and practical way—even the remarks above are but an abstract outline of what the book has to say. The whole is an illuminating survey of the present state of British science and its applications, accompanied by a host of proposals for its improvement. Nor is science viewed in a too severely utilitarian setting. Application is given heavy emphasis, as is natural in present conditions, but the cultural value of fundamental research is fully recognised and chapters are devoted to such subjects as 'Science in General Education' and 'Science as a Part of Culture'. In the introduction Professor P. M. S. Blackett comments that no such comprehensive review of British science has ever been made before, and in fact no official body exists which could undertake it. "This book," he concludes, "will have justified its production if it brings to a wider section of the public a realisation that such a central body is needed, and an understanding of some of the tasks which it should undertake."

Gerontologically Speaking

THE quest of the Alchemists was the transmutation of the elements and the Elixir of Life. The first is now an everyday occurrence in this atomic age, but the fountain of perpetual youth is still a dream, at least as far as Man is concerned.

Since Man, like the majority of living creatures, appears doomed to senility and death, the most he can hope is that he may be able to delay the beginning of senescence as long as possible and when it arrives to combat it with greater vitality than at present. Not only are we all getting older individually every day, but the average age of the population as a whole is getting higher as the numbers of the young and the old are out of balance. The fall in the birthrate and the years added to life by medical and social advances are resulting in a greater proportion of old over young, and a serious burden will fall on the decreasing younger part of the population if they have to support an increasing number of those who have had to retire into inactivity owing to the infirmities of old age. It will clearly be to the common good if the inevitable decline in physical and mental agility can be postponed as long as possible.

There are a great many aspects of ageing which can be studied. It would be a useful guide if some readily measured quantitative change associated with ageing could be measured, so that the relative importance of different factors could be assessed, as for instance, the relative contributions made by different glands and the value of hormone treatment. The number of birthdays that a person has passed is not necessarily a useful measure of his effective physiological age. One promising quality to measure may be the Basal Metabolic Rate—B.M.R. for short—which is the rate of heat production by the body when the subject is awake and lying down in comfortably warm surroundings, in a state of as complete mental and physical rest as possible.

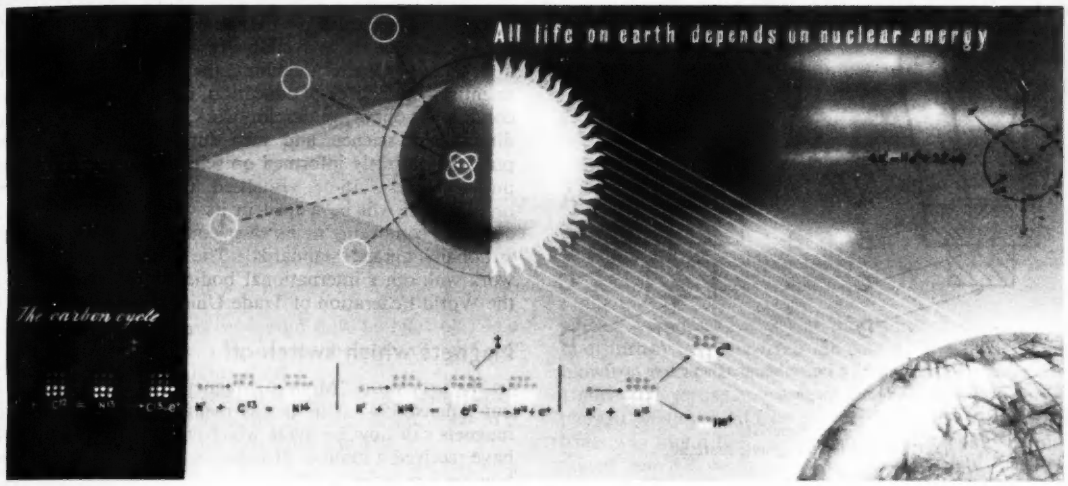
The B.M.R. can be calculated from the rate of oxygen consumption, and may be regarded as the minimum energy requirements of the body machine when it is just 'ticking-over'. It is usually expressed as calories per square metre of body surface per hour. It has been found that the B.M.R. is fairly constant for healthy individuals of the same age and sex, but diminishes throughout life from about 50 units in infancy, reaching around 40 units at the age of twenty, and is then almost stationary for the next twenty years; after forty it declines at the rate of about one unit for each decade.

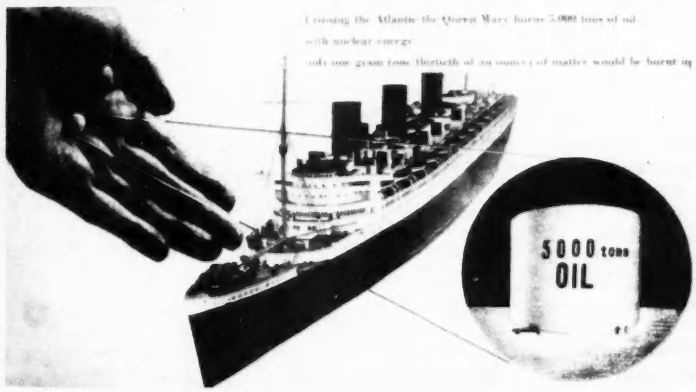
These values are the averages for groups of apparently healthy individuals, and as lower values are found when certain diseases are present, there is always difficulty of knowing whether or not the figures are being invalidated by pathological changes which are not readily detectable and which are bound to be commoner in the older groups. If the gradual fall after forty is taken to be a real effect and the B.M.R. to be an expression of 'vitality', then there must be a reduction in some of the basal activities of the body where energy is expended and the body machine must be running more slowly. It should be possible to correlate other changes in old age with those in the B.M.R.

Nutritional studies offer another experimental approach. Although one is especially interested in human old age, man himself is a rather unsatisfactory experimental animal. As it is reasonable to expect that the underlying fundamental principles will be common to man and other animals, rats and mice are used most frequently in nutritional studies, since very uniform strains are available and one can use numbers sufficiently large for satisfactory statistical analysis of the results.

Some interesting results have come from experiments in which nucleic acid was added to the diet of mice. This substance is an essential constituent of the nucleus of all living cells and is, therefore, intimately associated with cellular division, multiplication and growth. The American worker, Dr. T. S. Gardener, fed nucleic acid to 600 day-old albino mice throughout their lives, a twenty-thousandth of an ounce being given daily to each mouse, as an addition to a diet usually considered quite satisfactory. He found that the average life of the males was increased by 8·4% and that of the females by 7·4%. The interpretation of these results is, however, not a simple matter, and there are several theories—that nucleic acid is a food for the growth of the nucleus, and so results in the maintenance of a high proportion of nuclear material in the cell, which is a characteristic property of young and vigorous cells; or, alternatively, existing cells may be spared from destruction when additional nucleic acid has to be mobilised for cell-building; another possibility is that white blood cell production may be stimulated and greater resistance to infection thereby maintained, it being generally agreed that a decrease in resistance to infection is an important effect in ageing.

These positive results with mice have led Dr. Gardener into another interesting field, the nutrition of bees. The queen bee lays fertilised eggs in worker and queen cells, and the grubs that hatch are all fed initially on royal jelly —a material secreted by the workers. The grubs which are nourished solely on royal jelly throughout their larval life develop into queen bees, but those which are transferred to a diet of pollen and honey after four days become worker bees. Eggs or very young grubs can be transferred from queen cells to worker cells and vice-versa, and subsequent development depends entirely on the diet supplied, showing that there is only one type of egg involved. The queens live





ATOMIC TRAIN EXHIBITION

Two striking panels from the Atomic Train Exhibition organised by the Atomic Scientists' Association, which has already visited ten northern towns where it has aroused great public interest. The exhibition's itinery is scheduled to take in another ten places. The dates on which the exhibition can be seen are as follows: York, Jan. 19–22; Leeds, Jan. 23–28; Sheffield, Jan. 29–Feb. 3; Derby, Feb. 5–7; Coventry, Feb. 9–12; Nottingham, Feb. 13-17; Leicester, Feb. 18–21; Birmingham, Feb. 23–March 2: Shrewsbury, March 4–6; Swansea, March 8–13: Bristol, March 15–20; Cardiff, March 22–27; Oxford, March 29–April 3; Reading, April 5–8; London, April 9–20.

for about five years but the workers for only three months, and the question naturally arises as to how far the much greater life-span of the queen is a direct result of the exclusively royal-jelly diet. Analysis shows that royal jelly contains less carbohydrate than pollen and honey but is rich in nucleoprotein (which contains nucleic acid) and in vitamins of the B group and is the richest known source of the vitamin called pantothenic acid.

Dr. Gardener finds that the life of fruit flies is increased if royal jelly is fed to them, and has tried the effects of several of its components separately. Nucleoprotein, and the three vitamins pantothenic acid, pyridoxal and biotin, fed separately as additions to the diet of the flies, gave increases of life-span of 11, 27, 10 and 0% respectively, but a mixture of all four together gave the remarkable increase of 47%.

The conclusion that can be drawn from all these feeding experiments is that diets usually thought quite adequate for healthy development in fact fall short of that required for optimum life. Does a diet at present considered well-balanced and quite satisfactory for human nutrition suffer from some similar and undetected defects? Future work must try and solve this question.

The increasing interest now being taken in matters relating to growth and old age has led to the appearance in America of a new medical quarterly, the *Journal of Gerontology*, 'gerontology' being a word that is coming into frequent use to describe the science of ageing.

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Scientists' International

AT every stage of its development the scientific world has had to find new organisations to meet new needs. At first the problems were mainly internal, giving rise first to the national academies of the 17th century and later to the specialised societies of the 18th and 19th. In the 19th century, as the social effects of science became more apparent, new types of organisations developed—like the British Association, one of whose main functions concerned liaison between scientists and the general public. The increasing use of science in industry and civic affairs

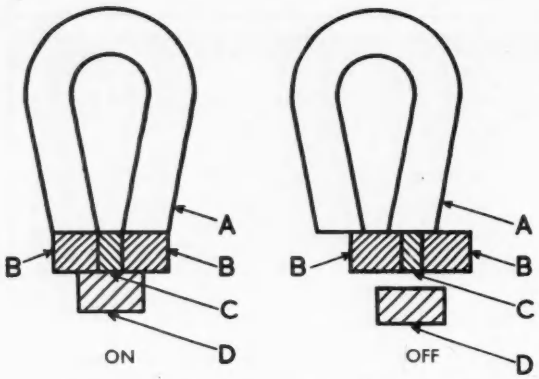


FIG. 1.—Switching off a horseshoe magnetic (*see text*).
A, Horseshoe magnet,
B, Pole pieces,
C, Non-magnetic material,
D, Object of ferromagnetic material.

led to the formation of organisations like the Institute of Chemistry (now the Royal Institute of Chemistry), concerned with creating and maintaining professional standards.

In the present century the increasingly wide employment of scientists on what has become almost a proletarian basis necessitated organisations to take care of salaries and conditions of work, while the more and more obvious perversion and frustration of science led to the need for an organisation through which the ordinary scientist could voice his opinion on the social relations of science. This produced, in Britain, the Association of Scientific Workers, which began (under another name) in 1918, and similar bodies in other countries within the last decade or so.

In the last few years it has become clear that national organisations of this last type are not alone sufficient. Problems of ensuring the proper and beneficial use of science are essentially international problems. For instance, a piece of biological or chemical research carried out in Britain may well find its most important potential applications in the ricefields of China. The increasingly scientific nature of modern war and the growing field of 'security' secrecy have transformed the problem of scientific communication from the mere matter of organisation it seemed to the 17th-century academies into a question thoroughly entangled with international politics. And so these various national organisations of scientific workers have found it necessary to come together and to found (in July 1946) the World Federation of Scientific Workers.

Among the objects of the Federation set out in its constitution one notes such items as "to work for the fullest utilisation of science in promoting peace and the welfare of mankind", "to encourage the international exchange of scientific knowledge and of scientific workers", "to improve the professional, social and economic status of scientific workers", and "to encourage scientific workers to take an active part in public affairs, and to make them more conscious of, and more responsive to, the progressive forces at work within society".

To begin with the Federation will pursue its objects chiefly by the interchange of information among its constituent organisations, so that the knowledge and experience of each becomes available to all. It is also preparing a Scientists' Charter, defining the rights and duties of scientists—standards of education, remuneration, working conditions, opportunities for work, and the control and direction of science, and such duties as seeing that the public is correctly informed on scientific matters affecting public affairs. It is visualised that each constituent organisation will be helped in its work by being able to compare conditions in its own country with these internationally agreed standards. The Federation will also work with other international bodies such as Unesco and the World Federation of Trade Unions.

Magnets which switch off

IN the article on "Modern Magnets" which appeared in our August 1947 issue it was mentioned that permanent magnets can now be made which will switch off, and we have received a number of requests for information about how such magnets work.

The principle employed is that of short-circuiting the magnet with a keeper, and can be explained by the following simple experiment. Consider a horseshoe magnet with its poles fairly close together (Fig. 1). If a piece of soft iron or mild steel were placed one on each pole, the magnet would still operate through these pole pieces provided they were kept apart by a piece of non-magnetic material. If now the soft iron pole pieces were displaced sideways until one of them bridged the gap between the poles of the horseshoe magnet, this pole piece would act as a keeper and short-circuit the magnetic flux. Any object

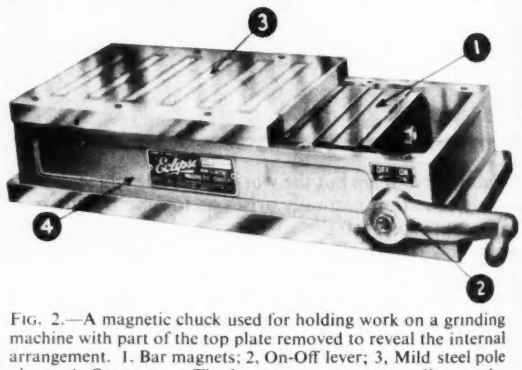


FIG. 2.—A magnetic chuck used for holding work on a grinding machine with part of the top plate removed to reveal the internal arrangement. 1, Bar magnets; 2, On-Off lever; 3, Mild steel pole pieces; 4, Outer case. The bar magnets, corresponding to the horseshoe magnet of Fig. 1, are magnetised in a vertical direction with similar poles at the top. Between these magnets, but not touching them, are parallel bars of mild steel, which become magnetised by induction in the opposite direction to the permanent magnet. The top plate consists of a mild steel frame with mild steel insets separated from the frame by a non-magnetic metal. The on-off lever slides the system of magnets relative to this top plate. In the 'on position' each narrow mild steel bar is covered by an inset on the top plate, and each permanent magnet by the main frame. The magnetic flux passes through a mild steel base plate at the bottom and any ferromagnetic object placed on the chuck at the top. When the chuck is switched off the top plate with its insets is staggered relative to the magnet and mild steel bars and, just as in the simple example with the horseshoe magnet, the magnetic flux is short-circuited and any object placed on the chuck is freed. (*Courtesy of James Neill & Co. (Sheffield) Ltd.*)

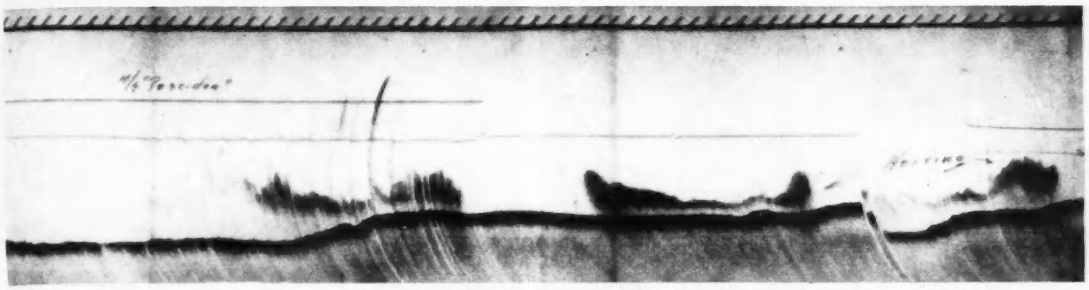


FIG. 3.—Shoals of herrings are revealed in this actual Asdic chart. (*Courtesy of Marine Instruments Ltd.*)

adhering to the pole pieces would now be released. The action of sliding a piece of iron over the poles of a magnet is much easier than pulling it off.

In practice the arrangement is rather more complicated than that of this simple example. One design used in a commercial magnetic chuck is shown in Fig. 2.

Magnetic chucks can be used to hold any ferromagnetic material, and are particularly useful for holding components, which, owing to their shape or brittleness, might be damaged by a mechanical clamp. An object with a smooth flat surface is held so tightly that it cannot be removed until the chuck is switched off. Besides saving electricity the use of permanent magnets obviates the need for leads which are necessary with ordinary electromagnetic chucks. Lifting magnets for separators and other purposes are also made using this device, and it is likely that other uses will be found for permanent magnets that can be switched off.

Asdic and the Fishing Industry

THE use of Asdic, the method of locating solid objects by means of the echoes produced when the supersonic waves generated by the Asdic transmitter are reflected from such objects, provided the Royal Navy with a very efficient means of detecting enemy submarines during the war.* Recent experiments carried out in the Antarctic and North Sea indicate that Asdic as a method for locating whales and shoals of fish may prove a commercial proposition.

At the end of 1945, following requests to the Admiralty from the whaling industry, Asdic sets were fitted in two new whale catchers, the *Southern Wilcox* and *Southern Wheeler*. One of the difficulties of the whale-catchers has been that while the 'blows' of the whale can be seen from a distance and the whale itself can be sighted up to 600 to 800 yards, the whale is lost sight of when it dives on realising it is being chased. One of the reasons for trying Asdic arose from the desirability of finding a method that would keep track of whales when they are out of sight under water. The Asdic equipment fitted to the whale catchers was of a standard type with minor modifications.

With these sets whales were detected, under the best conditions, at 1200 yards by the Asdic recorder, but it was soon apparent that when whales were over 800 yards from the catcher none of the assistance that Asdic gave in detecting whales was necessary, as at that range the whales were undisturbed by noise from the catcher and their frequent blowing gave sufficient visual indication of their course. Under 800 yards, however, Asdic aid in following submerged whales would be of very great benefit. In these trials was found that using Asdic contact could be maintained from 800 yards down to 60 yards. Below the 60-yard range Asdic assistance would be still more valuable, but the sets that were fitted for the experiments were found to be unsatisfactory for use at this very short range. The view of the experts of the Navy's Underwater Detection Establishment at Portland is that it should not prove impossible to construct a special Asdic set which would continue to keep track of submerged whales at less than 60 yards.

In the experiments to locate shoals of herrings, the Admiralty trawler *Valeta*, carrying a standard Asdic set, was used off East Anglia, while other trials were carried out in the Clyde Estuary and off the north-east coast of Scotland.

During November the herring in East Anglian waters are migrating southwards to the spawning-grounds off France. The fish are more active at night, and come near to the surface then. During the day they remain near the sea bottom, and any echoes obtained during this period are hard to distinguish from echoes from the sea bottom so that the trials took place at night. Good echoes were obtained when near fishing nets containing reasonable catches of fish, while a good trace was also obtained from a shoal of herring.

The Clyde trials were a failure, however, chiefly owing to bad weather and scarcity of herring. The experiments off the north-east coast of Scotland proved more successful, the shoals being located, when weather conditions were favourable, at ranges up to 2000 yards. It was frequently found that an echo 'disintegrated' into a number of small echoes when the ship approached to within 200 yards of the shoal. The explanation was that the shoal had split up into smaller shoals.

In summing up the herring trials the Admiralty say that there is no doubt that the Asdic will indicate the presence of herring shoals under favourable weather conditions, particularly in the upper layers of the sea. But they emphasise that a skilled operator is required to differentiate between the various kinds of echoes recorded by the instrument. They do not think the best results would be obtained if the sets were fitted to vessels of the herring fleet; these would have their greatest value if fitted in a special ship whose sole function would be the location of the best fishing grounds.

* A description of submarine detection by Asdic was given in the article "Science in the Naval War", DISCOVERY, December 1945, p. 363.

FIG. 1.—(*Left*) A distant view with light haze, taken on a panchromatic film. (*Right*) Same view photographed on an infra-red plate using a visually opaque filter on the lens. Notice the greater detail in the distance and the white appearance of the vegetation.

Infra-red Photography

G. A. JONES, M.A., A.R.I.C., F.R.P.S.

INFRA-RED photography is one of those techniques which are from time to time brought to the public attention, usually in connexion with some world-shattering invention for seeing through fog or in total darkness. After reading *Photography by Infra-red** one can certainly appreciate the popular appeal of this subject, though it is both a much wider and a much subtler appeal than that suggested by the nine-day wonder. Dr. Clark is an acknowledged expert on his subject and the first edition of his book has been used throughout the world during the war years as the standard reference book on all aspects of infra-red photography. In it he ranges from dark-room practice to methods of obtaining infra-red sensitivity in photographic material and from sources of infra-red radiation to applications of infra-red photography. In this last lies the chief attraction of the book for those who are reading simply for general scientific interest. Taking a dozen random examples, we can read how infra-red is used in connexion with the rusting of tin-plate, the interiors of furnaces, lubricating oils, the detection of new stars, pearls, ecological surveys, the examination of chitin, varicose veins, coal petrology, the deciphering of ancient manuscripts and colour printing.

Luckily there is a logical connexion between all the diverse applications of infra-red photography. The infra-red region is, of course, that part of the electromagnetic spectrum in which the wavelengths are longer than those in the visual region (see Fig. 3). At the shorter wavelength end it is hard to distinguish between just-visible 'dark red' and invisible infra-red, while at the other end the region merges into that of heat rays. So light and heat are linked. Photographic materials can be sensitised to the part of the infra-red just outside the red—roughly between 7000 and 13,000 A. As the eye is insensitive here, photography can be carried out in what appears to be total darkness.

* *Photography by Infra-red*, by Walter Clark, (2nd edn. 1947. Chapman & Hall, London, pp. 471, 36s.).

Apart from this, as one might expect, an object does not necessarily reflect or transmit infra-red to the same extent as white light, any more than it reflects, say, red and green to the same extent. For this reason it has a specific infra-red 'colour', i.e. it may appear to be of a light colour when photographed by infra-red while appearing dark to the eye, or vice versa. Add to this the lower scattering of infra-red radiation due to its longer wavelength and you have the basic reasons behind its use for all the many thousands of diverse purposes.

It has been widely supposed that infra-red provides useful means of penetrating thick mist and fog. This is quite erroneous, and Dr. Clark spends two separate chapters explaining just what penetration it can actually achieve. He considers the problem both from its theoretical aspects and in the light of practical tests and concludes that mists, fogs and clouds which are white or neutral grey in colour cannot usefully be penetrated at all but that a light haze, appearing blue to the eye, can very well be cleared. This does not usually result in a very marked increase in range of vision but it does increase the apparent contrast of the subject and hence the amount of detail which can be seen. This is clearly shown in Fig. 1, where distant detail is much clearer in the infra-red record of the scene.

Dr. Clark points out one interesting fact which has been largely ignored previously: to penetrate thick fog of fairly large particle-size a very long wavelength radiation would be needed, say about 200,000 A.—but the energy in sunlight at such a wavelength is negligible and in any case the atmosphere exerts a strong absorption beyond a point not very far from the limit of the present region of photographic sensitivity. So the use of infra-red is never likely for any form of fog penetration—though this is immaterial, as radar devices can now be used for such purposes with increasingly high efficiency.

Infra-red photography has been used for haze penetration largely in the field of aerial mapping. Here the

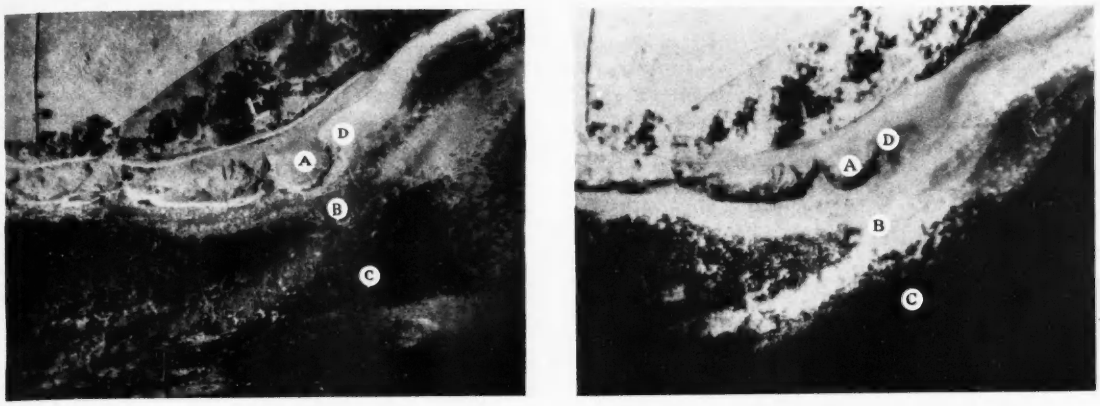


FIG. 2.—Detection of different types of seaweed is possible by the comparison of photographs made by green light and by infra-red radiation. The left-hand photograph was taken using a green filter with a panchromatic film. It shows a belt of probable seaweed-covered rock (*B*) and a belt of bottom weed (*C*). The right-hand photograph was taken by infra-red, and shows *B* as weed and not bare rock because of its high reflection. Rock (*A*) and shingle (*D*) show dark, while under-water weed is invisible. (*Courtesy Majors P. K. Wiggs and P. E. Conant and the Army Photographic Research Unit.*)

heightened contrast is sometimes of value, though other factors also enter to a considerable degree. Infra-red aerial records are of value for a number of reasons quite apart from haze penetration. Water absorbs infra-red quite strongly, and lakes and rivers are thus much easier to detect in infra-red records.

The differentiation possibly by infra-red photography has proved of some value in the aerial detection of military camouflage. To be fully effective, camouflage must operate against both visual and photographic observation. It is generally considered that complete protection of any large installation by these means is impossible, as careful photographic analysis will always reveal the real form of the objects under suspicion. On the other hand, efforts have been made to achieve this ideal and the appearance of camouflage in photographs has been of considerable interest. Owing to the fact that natural and artificial materials may reflect infra-red to different extents, the use of infra-red aero film is an obvious way of trying to detect camouflage which is visually perfect. For example, a cloth covering may be dyed green to match surrounding grass and trees exactly, but if it does not photograph white, as the vegetation does, it will easily be detected by infra-red film. For this reason all paints, dyes and materials used for camouflage work are tested by photographing them on a panchromatic material and on an infra-red-sensitive one. Unless the two photographs are almost identical the camouflage material concerned is discarded. In this way, cloth and paints can be selected which are as difficult to detect from the air by infra-red photography as by normal panchromatic records, provided they are properly used on the ground. In either case however, camouflage can usually be detected by careful stereoscopic examination of the aerial photographs.

Turning from war-time to peace-time applications of aerial photography, infra-red photography from the air can be used to pick out many other materials which are visually almost identical. For example, live and dead vegetation and different types of living vegetation are clearly differentiated. Fig. 2 shows some aerial views of

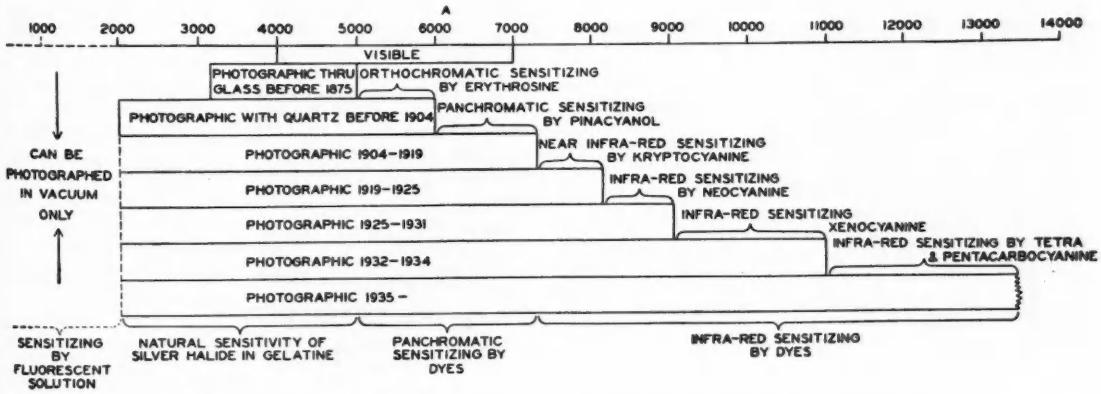


FIG. 3.—Extension of photography into the infra-red range (7000–13,000 Angstrom units roughly) depended on the development of new sensitisers.

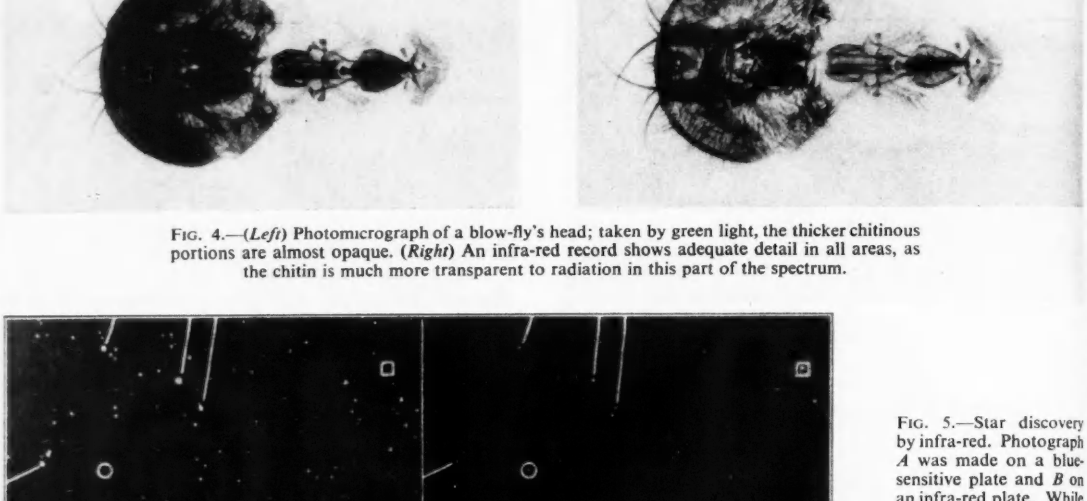
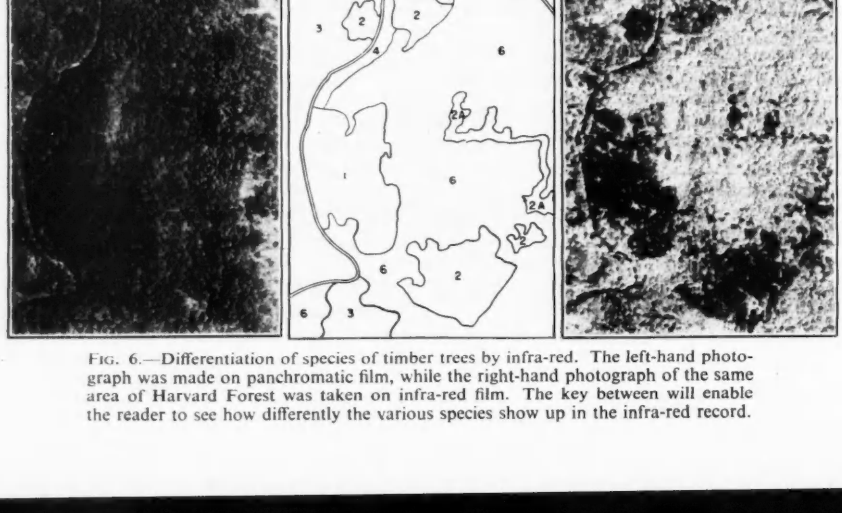


FIG. 4.—(*Left*) Photomicrograph of a blow-fly's head; taken by green light, the thicker chitinous portions are almost opaque. (*Right*) An infra-red record shows adequate detail in all areas, as the chitin is much more transparent to radiation in this part of the spectrum.

FIG. 5.—Star discovery by infra-red. Photograph *A* was made on a blue-sensitive plate and *B* on an infra-red plate. While some stars show on both (some such stars are indicated by white lines from the edges), infra-red stars marked by squares and circles in *B* are invisible in *A*. (*Yerkes observatory photograph.*)



1. White pine, old growth.
2. White pine, young growth.
2a. White pine, old trees.
3. Mixed white pine, hemlock and hardwoods.
4. Hemlock.
5. Mixed hemlock and hardwoods.
6. Hardwoods.

FIG. 6.—Differentiation of species of timber trees by infra-red. The left-hand photograph was made on panchromatic film, while the right-hand photograph of the same area of Harvard Forest was taken on infra-red film. The key between will enable the reader to see how differently the various species show up in the infra-red record.

part of a coastline taken by the Army Photographic Research Unit. In the normal photograph the underwater portions cannot clearly be distinguished from those in the air, while the patches of weed all look the same. In the other the water records as black while the seaweed-covered rock can be seen to be above the surface and can be clearly differentiated from the rock itself. Similarly, in infra-red photographs of forests, softwoods and hardwoods can be distinguished, and indeed distinction can to some extent be made between different species of trees. (Fig. 6.) The forester can not only cover vast areas by photography, mapping out the parts covered by various types of timber, but can also gain an idea of the ages of the trees and their heights. The older the tree the darker it appears in an infra-red record, though care must be taken to allow for the differences introduced by the slope of the ground, the angle of the sun and other variables. Skilled interpretation is needed, though no more skilled than that carried out every day during the war in all the air forces concerned.

In general, green foliage records in infra-red photographs as very light in tone, often almost white. This appears to be due to the great transparency of chlorophyll, the green colouring matter of leaves, which is relatively opaque to white light but allows infra-red radiation to pass through the surface layers and become scattered and reflected in the underlying parenchyma where the cells are separated by air spaces. This is of value as it often enables diseased or dead portions of the plant to be illustrated clearly when they are barely visible to the eye.

In much the same way, many dyes are very transparent to infra-red and irregular dyeing of fabrics, damage to the cloth and grease or dirt can be clearly shown up when the dye is so dark visually as to prevent such observations. This also enables dark dyed fibres to be studied more easily under the microscope.

Materials which are more transparent under infra-red include silver-stained biological preparations, fossil- and coal-sections, some plastics and the dark chitin present in many insects. The structure of many insects contains chitin, which is very dark visually and prevents proper examination of anything but thin sections. It is customary to bleach it with potash, a delicate operation which may lead to damage. Infra-red photomicrographs (Fig. 4) often show as much detail as if bleaching had been carried out and at no risk to the specimen. Certain fossils contain carbonised organic remains and this, too, has been found to be relatively transparent to infra-red. In this way the structure of the scales of fossil fishes and of hairs from mammoths has been examined, among other studies. Infra-red techniques are also extensively applied in other fields of photomicrography. Apart from many biological examples, the amount of carbon in used motor oils, together with the particle shape and size, has been examined, results depending upon the fact that carbon is opaque to infra-red radiation while most oils are not. In metallurgical work, rust films on the surface of tin-plate specimens can be penetrated successfully to show the centres of corrosion at pores in the plating below.

In many cases infra-red penetrates other materials which do not appear especially dark to the eye. One of the best examples of this is the human skin. Infra-red may penetrate the skin and flesh to a depth of some millimeters and is thus capable of showing clearly parts of the superficial venous network, especially when the veins are dilated as, for example, in varicose conditions. There are many such applications in medical work, depending on the transparency of certain layers to enable underlying conditions to be studied. Thus the iris of the eye can be observed through an opaque outer cornea, and the eye can be filmed by infra-red to study the behaviour of the pupil in total darkness and the time it takes to dilate to its maximum size after the white light is turned off.

One of the chief attractions of infra-red work is the many applications to which it can be put in what one may call, for want of a better term, 'investigative' work. In criminology, erasures and forgeries have been shown up and many other applications found. In documentary photography, old manuscripts, papiri and charred papers can sometimes be deciphered when they are quite illegible to the eye, while deleted passages can be read if the overlying ink is transparent to infra-red. In the study of paintings, varnish and some pigments may be relatively transparent and allow the underlying work to be studied. Characteristic brush marks so revealed (Fig. 8) may assist in determining the authenticity of the painting.

Apart from these special techniques, which all rely upon the way in which infra-red is reflected or transmitted, are some cases where no record could exist without an infra-red sensitive material. For example, certain stars radiate very little white light, are thus almost invisible and may not record on normal astronomical photographs while

FIG. 7.—An infra-red photograph of an operator in the Kodak factory examining the end of a reel of 35 mm. film by means if an infra-red image converter.

FIG. 8.—Detail from Tura's "St. Jerome" photographed (*left*) on a normal panchromatic plate and (*right*) on an infra-red plate. In the former the surface appearance is shown but in the latter the underlying brushwork can be seen. In this way the characteristic technique of the painter can be studied without damage to the work. (*By permission of the Trustees of the National Gallery*).

showing strongly in records made on infra-red plates. On the other hand, certain nebulae do not appear at all on infra-red photographs while stars behind, normally hidden by their luminous haze, can be clearly seen.

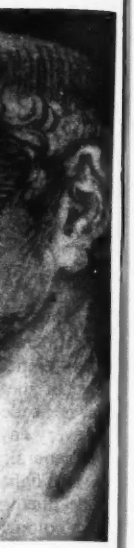
Photography in the dark can be carried out provided infra-red illumination is present. Under normal conditions in a darkened room or out of doors at night no infra-red is, of course, present and photographs cannot be taken, so that stories of photographs at night showing the countryside as if by daylight are quite without foundation. Dr. Clark devotes a whole chapter to the subject of sources of infra-red radiation. It is fortunate that ordinary electric filament lamps have a large output of infra-red in the photographic region and, in general, they are the most useful sources to use. Most infra-red plates or films are also sensitive to white light, so, for infra-red work, a filter must be used which absorbs white light and allows only the infra-red to pass through. Such filters are available in a number of types, cutting off at different wavelengths. For merely examining specimens it is only necessary to place the filter over the camera lens and there is no need to work in the dark. Where photographs in total visual darkness are required, filters have to be placed over all the lamps used, so that their infra-red output is utilised but no trace of white light transmitted. Such techniques have been used for physical research, blackout photography during the war and for studying machines and factory operatives at work in total darkness. Fig. 7 shows an operator using an infra-red converter to examine the end of a roll of ordinary photographic film in total absence of white light, which would 'fog' it. This instrument is, of course, not photographic and enables the eye to see an image on a fluorescent screen in total darkness, so that the operator can see to carry out her work. She could not be recorded at work without infra-red plates, however.

Infra-red radiation is emitted by hot bodies when no light from them is visible. Above a temperature of about 250° C. this contains some wavelengths to which infra-red photographic materials are sensitive. Hot materials can therefore be recorded by their own emitted radiation, provided they are hot enough. They appear in infra-red photographs as 'white-hot' though they may appear cold to the eye even in the dark. For example, the infra-red given out by an electric iron is ample for purposes of illumination. This technique is used to study the temperature distribution over furnace walls, internal combustion engine cylinder-heads, electric appliances and so forth.

All these applications of infra-red photography lend interest to the history of the development of the technique. All methods of sensitising photographic materials to radiations with wavelengths longer than that of blue light depend upon the incorporation of a suitable dye in the material during manufacture. Prior to the introduction of Dicyanine early in this century, photographic plates were insensitive beyond about 7300 A. This sensitiser was difficult to use and it was not until Kryptocyanine was introduced in 1919 that reasonably satisfactory infra-red materials became available. Even this only sensitised as far as 8000 A. but, in 1925, Neocyanine extended the limit to 9000 A.

In the period 1931–5 a large number of excellent infra-red sensitising dyes were discovered and these pushed the available limit of sensitivity to beyond 13,000 A., while commercial plates are now available with which work can easily be carried out in the region of 10,000 A. The general photographic qualities of the plates have also been improved and materials are on the market which need only the same exposure in sunlight, using a visually opaque filter, as ordinary fast panchromatic plates with no filter.

Dr. Clark's book is not only a comprehensive authoritative treatise on the theory, practice and applications of infra-red photography. It is also a valuable text-book on general scientific photography, including chapters on dark-room design and practice, and the characteristics of photographic materials.



What is Operational Research?

MAURICE GOLDSMITH, B.Sc. (Econ.)

WHEN in January 1943 Air Chief Marshal Sir Philip Joubert, Commander-in-Chief of Coastal Command, spoke at a conference called by the Association of Scientific Workers he gave the first public blessing to the new relations that had developed between scientists and military chiefs. "This novel intrusion into the military circle"—as Sir Philip described Operational Research—was by the end of the war accepted by Planning Staffs in all Commands, both in Britain and the U.S.A. Indeed, some OR workers affected changes in overall strategy; and all were concerned with tactics.

Operational research has great peace-time potentialities, but to appreciate how it can be developed in peace it is necessary to be very clear about what OR is and what it has done.

The term 'Operational Research' was, to the best of my knowledge, first used by Sir Robert Watson-Watt. With his colleague, Mr. A. P. Rowe, he told the British Association* at Dundee, they visualised OR as "the application of the basic scientific methods of measurement, classification, comparison and correlation to the selection of means for attaining, with the least expenditure in effort and in time, the maximum operational effect which could be extracted from the available or potentially available resources in personnel and material.

"We visualised the operational researcher as requiring dual ranges of knowledge. On the one hand, a wide and fairly detailed knowledge of the technical possibilities and limitations of the equipment in use or capable of development; and, on the other hand, a close personal knowledge of the working conditions in which it was to be used and of the people who were to use it. The operational researcher must be equally at home, and equally welcome, in the development laboratory, in the squadron mess, on the tarmac with the Leading Aircraftsman, and in the staff conference.

"He will be constantly in pursuit of numerical values, however rough the approximation; he will be trying constantly to isolate the consequences of the planned variation in one of the determining factors from all other variables in the ensemble under study."

The First Operational Research Section

A few days before the second World War began, the first OR section was set up at Fighter Command H.Q. It was made up of a few scientists whose job it was to see that the newly-introduced radar equipment—so essential to the then outnumbered R.A.F. because it was an early-warning system—was handled properly. This apparatus was too complicated technically to be handled as a routine matter by R.A.F. personnel. The operators had to be trained and supervised, the actual working quality of the equipment in the field had constantly to be assessed, and there were problems arising from the organisation of the mass of information that flowed from the radar sites along the coast.

"The Operational Research Section," to quote Sir Philip Joubert, "was charged with the surveillance of the warning system and had under its control a flying squad (in quite the literal sense) of repair and servicing engineers. When, as a result of observation made by the Operational Research Section or from reports made by the operating personnel, a falling-off in efficiency became manifest, the flying squad was dispatched to put things right. This scheme worked well and soon gained the confidence of the Air Staff at Fighter Command."

All this meant that the scientist was more intimately drawn in at a technical level than ever before. He was winning the co-operation of the military expert: and, in addition, he was being brought in to advise on certain tactical problems. Sir Philip explains this important development. "The desirable situation is when the Service side realises a series of needs and passes straightforward questions to the scientist. Such questions must, of course, be capable of consideration by scientific methods. By this I mean they must be questions of fact, not of theory. The facts of the war in the air can be clearly stated. For example, it may be necessary to decide how many flying-hours with so many aircraft are required to achieve a certain result. Given past experience, scientific analysis will quickly provide the answer to this question. . . . The position becomes more complicated when the military staff are not quite certain what they want and are unable to state their case clearly. The scientist must then grope for his solution. . . . It is, therefore, of the utmost importance that the military staff should give the scientist the clearest guidance on his duties. If, however, the scientist never initiates any action and always waits to be asked a question by the military staff, he will lose half his value . . . it is certain that the advent of the Operational Research Section has resulted in many difficulties being cleared away by the sound advice they have given. . . . The Operational Research Sections have a further duty. By reason of their experience and their associations with the outside world they are frequently aware of developments which do not normally come within the knowledge of military staffs. It is obviously, therefore, their business to call attention to such developments."

Thus the role of the scientist in war began to change: and OR was the instrument of this change. What then is OR? It is market research, consumer research, time-and-motion study, social survey, method research. All these are, I believe, aspects of OR. What makes OR different from each of these individually is the fact that it is primarily concerned with the consumer. Market research, for instance, is definitely tied up with a producer. It is not the function of the market researcher to protest against the sale of trashy goods, whereas during the war OR had constantly to be concerned with the users' demands, and research, development and production were all related to this fundamental. Again, time-and-motion study with its emphasis on the individual worker as a mechanical

* A report of the British Association's Division of Social and International Relations of Science's discussion on operational research appeared in *Nature*, 1947, Vol. 160, p. 660.

unit in a belt of production has not been concerned primarily with organisational and administrative questions which view the worker as a member of a team, first in a small group of workers at his own level, and then as part of a wider management-workers group. Instead, time-and-motion study has too often aroused the deepest "Luddite hatreds" in the worker. OR works within a different context. It is the scientific study of aspects of a functioning system having the aim of providing those responsible for execution with a quantitative basis for decisions. Another definition—which comes to the same thing—by a leading scientist describes OR as applying the techniques of the competent scientist to large-scale human operations as a whole "with the aim of fitting the operation to its purpose and of measuring the effectiveness with which the operation is carried out".

Thus, the OR worker can never consider technical improvements in isolation. They must always be related to organisational and human factors.

This is how OR worked in practice in war-time. My first example is in the social field, because here the application of OR principles is unexpected, and therefore most striking. Shortage of man-power was a serious problem during the last war. Within a short while it was found absolutely necessary to make the best possible use of available human material. As Professor F. A. E. Crew told the British Association at Dundee, the Services had "to turn to the biological and social sciences for the satisfaction of their urgent requirement, the provision of men who in virtue of their physical perfection, native intelligence, and acquired skills, and of their undertaking of and belief in the rightness of the cause they serve, can make the fullest possible use of the things with which physical science has so abundantly endowed them". It was because OR experts came to handle purely social problems that "a tank, previously regarded merely as a mobile gun turret, suddenly comes to be accepted as a carapace of a living creature whose anatomical dimensions, physiological needs, and emotional reactions ought to have been the dominant considerations when the tank itself was but a design on a drawing board". Thus, for OR workers problems of health, morale, efficiency and equipment are all linked.

Research on Tactics

Not only were scientists during the war employed at a technical level, but also at tactical and strategic levels. They were not only concerned with the use of weapons and equipment under operational conditions, but also with such tactical problems as the relation of different types of formation flying to the accuracy of bombing, whether it was better to bomb enemy ships at sea or to blitz their ports, and so on. "Scientists", states Professor S. Zuckerman, "with their understanding of the techniques involved, with their appreciation of the tactical problems that had to be overcome, and with their emphasis on objectivity and statistical method, could arrive at solutions about tactics which could have been derived only accidentally by other methods."

Dr. Charles Kittel (in *Science*, 1947, Vol. 151, p. 2719) gives some graphic examples. Firstly: "Statistics of the losses of R.A.F. Bomber Command aircraft over selected German cities indicated that the percentage of aircraft lost fell off as the number of aircraft participating in the raid increased, suggesting that the German defences were being saturated. If, then, the number of aircraft is increased over the saturation limit, the number of casualties should remain constant, and the *effectiveness ratio*, tons of bombs on target/own aircraft lost, should therefore increase. On the basis of this analysis the first thousand-plane raid in history was made by the R.A.F. in 1942; the results of this and subsequent large raids confirmed the prediction." Second: "Squadrons of B-29's based in the Marianas for the purpose of bombing Japan were able to put in a fairly definite number of flying-hours per month, this time being distributed between operational missions and training. If no time is spent on training, it is found that the average proportion of the bomb load dropped on the target is low; if all the time is spent on training, obviously no bombs will be dropped on the targets in Japan. An analysis of the improvement in bombing accuracy with training indicated that the maximum bomb weight on the target was achieved if about 10% of the flying-time is spent on training and 90% on operational missions; it was further shown that this distribution doubled the bomb weight on the target obtained with the original distribution of about 4% training and 96% operations. Training problems of this character are encountered in many situations in civilian as well as in military economy."

Now Professor P. M. S. Blackett, who was in charge of OR at the Admiralty, has stated that "the stability of certain factors involved in operations appears rather unexpected in view of the large number of chance events and individual abilities that are involved in even a small operation. But these differences in general average out for a large number of operations and the aggregate results are often found to remain comparatively constant. It is applicable whenever operations have been in progress and tactics have been sufficiently stabilised, as they often are for months at a time, for definite experimental data on the results of past operations to be obtained. It should be remembered that the technical instruments of warfare do not change rapidly owing to the long duration of development and production. And even tactics cannot usually change very fast owing to the necessary duration of training. Thus the condition of relative stabilisation of operational technique is quite often fulfilled."

This means, Dr. Kittel points out, that it is possible to discuss a problem in terms of an exchange rate. The exchange rate is essentially the ratio of output to input for a given type of operation, as measured in suitable units. Dr. Kittel quotes a specific example: "The British had laid down a programme for building a certain number of escort-type vessels in 1943. These vessels could be equipped for minesweeping or for anti-submarine duty. A study of the exchange rate, *merchant vessels saved/new naval escorts built*, indicated the importance of the anti-submarine escorts."

Further, it was found that the effectiveness ratios based upon these exchange rates was a constant for different theatres of war. For example: "The figure of 60 mines laid ship sunk has been found to occur in every aircraft mining campaign—German mines in British ports, British mines on German routes, and U.S. mines on

Japanese routes." Thus, data gathered in one area could be applied in another. "The average number of rounds from the five-inch guns of destroyers required to break up a Japanese pillbox on Tarawa could be expected to be approximately the same as the number of five-inch rounds required to destroy a German pillbox of the same size on the Normandy coast."

Effect on Strategy

At the strategic level the influence of the scientist was more remote. But clearly the answers to tactical problems had an effect on strategy. For example, Professor S. Zuckerman is the man primarily responsible for the fall of the island of Pantellaria. He calculated to the last detail the number of forces all of kinds required to lead to the capitulation of the island: and it worked out according to plan. This experiment was the prototype for the invasion of Italy. More use could have been made of the scientist at the highest level. However, by the end of the war scientists were working in all fields and at all levels. Up to the end of 1945 some 365 scientists had been employed in Army Operational Research; they wrote some 380 reports or papers and nearly 600 memoranda. The maximum number so employed at any one time was about 174. On the strength of the 21st Army Group were 12 officer-scientists, who were at the front from D-Day until July, 1945. They wrote some 40 reports. In the 14th Army in Burma, the OR section was concerned with problems of organisation and supply, and particularly with wastage of manpower.

Some social scientists have expressed annoyance at the suggestion that OR workers have introduced something revolutionary into social affairs. They are particularly hurt by the fact that all the leading OR scientists were natural scientists by training. The more far-sighted social scientists recognise that this is an accurate reflection of the backwardness of social science. Technically, on the whole, the social scientists are not equipped to introduce measurement into social problems. This is coming: but during the war it was only the physical scientist who—to quote a minute by Professor Blackett—could "encourage numerical thinking on operational matters, and so help to avoid running the war by gusts of emotion . . ." These natural scientists did work of fundamental importance in their handling of what were essentially problems of social organisation. In addition, they demonstrated the importance of the mixed team of scientists. Here men with different techniques discussed a common problem: and showed by their often brilliant solutions that little experience of weapons or warfare was necessary so long as they worked together.

These seem to me to be the important factors in OR work. Firstly, direct daily contact by scientists with operational personnel. This gave an essential intimacy and understanding between the 'consumer' and the 'adviser'. Second, the findings of scientists were put into application by commanding officers, because of the strong centralised organisation and because of the singleness of purpose which united all ranks and which made them co-operate to carry out orders. Third, because of this high morale the Forces were themselves anxious to secure the best possible solutions to problems, and thus the scientists were deliberately encouraged when they had shown that they were capable of defining problems which the ordinary person could see existed, but the nature of which he could not recognise.

Peace-time Possibilities

What application has OR in present peace-time conditions? OR techniques can, I believe, be of great assistance in helping to raise the levels of productivity and of production generally. Because of shortages of manpower and materials main emphasis must be placed on increasing productivity, that is increasing output without increasing effort. This means that there must be immediate attention to such organisational problems as increasing the level of efficiency. The aim must be not to antagonise the workers by complete emphasis on one aspect only, that is the maximum production of articles, but to make them accept the process by taking into account such interrelated factors as technique, layout, organisation, personnel and administration. This is essentially Operational Research work. In industry, however, the scientist is in the main a back-room boy, though the Board of Trade and the Ministry of Supply, however, recognise the importance of the scientist in this context, for the former runs a Production Efficiency Service as a service to firms, and the latter is responsible for supervising the efficiency of those organisations which they subsidise.

But the setting-up of such services does not mean that OR will be successfully applied. There must be a good morale throughout the organisation. That is, there must be a unity of purpose for employer and worker. Without this Operational Research will get nowhere. War-time experience has shown that this co-operation can best be achieved through the Joint Production Committee. Firms I have visited where these Committees* exist have impressed me by the general enthusiasm and efficiency.

Application in Industry

OR techniques can be applied not only at factory level, but also in industries generally. Thus, the Working Party Reports have made clear that many of our industries are woefully backward technically. Some, for instance the Report on Cotton, refer directly to the need to employ OR methods. It is recognised that the various Research Associations have not in the past developed either the initiative or had the intimate contact with the administrative and executive sides to do this work. That is why there are high hopes about the Industrial Development Councils which are to be set up under the Industrial Organisation Act, for they are scheduled to carry out OR investigations.

The best field, of course, for OR work is in the nationalised industries. In these there is centralised control; and,

* The importance of a good Joint Production Committee was underlined in a letter in DISCOVERY (July, 1947) by Mr. K. Campbell, chairman of the Joint Housing Committee of the Association of Scientific Workers and the Association of Building Technicians. He wrote that in the Forces "the operational research worker could expect to obtain co-operation just as much from the rank-and-file and from the commanding officers". This was not so in the building industry, because "co-operation between masters and men for the promotion of efficiency is virtually unknown . . . every encouragement should be given to the formation of joint production committees on building sites".

whatever the frictions that accompany the early days of nationalisation in some industries, there is a common unity between all grades of workers. In the coal industry the former scientific adviser to the War Office, Sir Charles Ellis, who was largely responsible for the development of Or in the Army, has stated that he intends to ensure that OR work will be carried out at all levels within the National Coal Board. Indeed, the organisation of scientific work and the representation of scientists in all committees at all levels makes clear that this is so. The Ministry of Civil Aviation has set up special OR units to assist the introduction of radar and other technical equipment, and to study the organisation of the British Overseas Airways Corporation.

Operational Research and Housing

The National Health Service, due to begin next July, will find it to advantage to employ OR techniques, as did the Medical Services during the war. This is because industrial problems cannot be successfully tackled without relating them to general problems of health, morale and efficiency. The best example of this is to be seen in the work of the Department of the Chief Scientific Adviser to the Ministry of Works. The aim is to build a house which will provide the best possible solutions to the problems of how people can live together with a minimum of friction, and what type of physical environment can be provided which will enable the bringing-up of a healthy family. Therefore scientists are gathering details of the living habits of human beings in houses. It is strange, but true, that very little is known about this. In charge of this project is one of the leading war-time OR workers, Professor J. D. Bernal.

Also of great importance as an aspect of OR work is the Organisation and Methods Department of the Civil Service. This department has been greatly stimulated by the comments in the Fifth Report of the Select Committee on Estimates (published in August, 1947) recommending an extension of its use. The Organisation and Methods Department was begun in the Treasury in 1942 "to help adjust and re-design the Government's machinery of administration in view of the shortage of man-power and the increasing extent to which the Central Government is assuming responsibility for economic and social affairs". Its purpose is to secure maximum efficiency in the Government's executive machinery, and by the expert application of scientific methods to organisation to achieve economy in cost and labour.

Mr. R. G. Casey in a speech in 1946 to the Australian Institute of Industrial Management gave this description of how the Organisation and Methods Department works. "Their first question when they tackle a new enterprise whether it is an industry or a Government Department is: 'What is this show required to do?' They quite properly insist on getting this down precisely in black and white. They then subject the head of the enterprise and the head of each branch and section to critical cross-examination as to his functions and how he carries them out, including his relation with the man above, and the people below, and the people on each side. They almost inevitably have considerable difficulty in getting individuals to be precise, particularly in the case of an old-fashioned enterprise or department. However, they insist on precision and if they fail to get satisfaction from any individual as to his functions or relations, they endeavour to build up what they believe they should be from the man above and the people below and on each side. When they have gone right through an organisation in this way they have a pretty good idea as to what it is all about.

"They then sit down with all the evidence they have patiently collected and see what improvements they can work out. The flow sheet of responsibility and authority is the main framework. When that is settled to their satisfaction, they deal with the location of typists' pools, registry, telephones, messenger and dispatch services, returns, accounting and all the rest. They examine all returns and reports, and endeavour to ensure that only the facts and figures that are really needed are made the subject of returns. They investigate the mechanical side in use and whether more office mechanisation is justified and, if so, what sort. They investigate and report on the lighting, ventilation, sanitation, rest facilities and all else that has to do with the comfort and convenience of employees. When all this patient and painstaking inquiry is carried out by intelligent individuals who have done the same sort of thing a great many times before in a wide range of activities, it is not difficult to understand how they are able to recommend changes that make a notable improvement in the smooth running and effectiveness of the enterprise under examination."

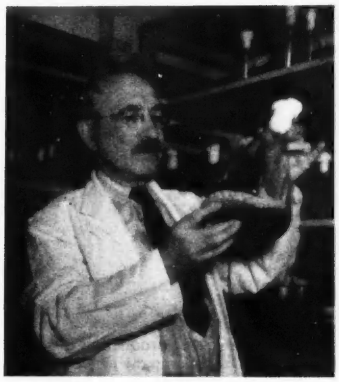
At Cabinet level, where the overall economic policies for the country are formulated, it must be recognised that those conditions which led to the appearance of OR in war-time exist now—the need for the most efficient use of men and materials to raise the productivity of the individual worker and production generally. Certain members of the Cabinet recognise that it is no longer possible to bridge the gaps between imports and exports merely by exhorting people to work harder and longer. What is needed is a scientifically determined system of priorities together with high-pressure short-term research—not excluding also long-term work. In this context Sir Henry Tizard's Advisory Council for Scientific Policy and Sir Edwin Plowden's Central Economic Planning Unit might be regarded as the OR Sections. In fact, the machinery for the application of OR techniques exists: and so does the man-power—economists, engineers and scientists, although attention will have to be paid to the training and development of new forces.

Operational Research is not a magic method which in itself will solve our problems. It is important because it does represent a new way of using scientific methods. Given the ability on the part of the Government to implement the recommendations of its scientific advisers, and given public co-operation, these war-time techniques can be successfully applied to the problems of today.

Streptomycin: A Progress Report

E. S. DUTHIE, M.B., Ph.D.

THE discovery of the sulphonamide drugs (prontosil 1932, sulphanilamide 1935, M & B 693 in 1938, etc.), followed by the even more spectacular success of the mould product penicillin in 1941, provided for the first time really effective remedies for a number of the more acute and hence more rapidly fatal forms of bacterial infection. Nevertheless, many important bacterial diseases proved to be insensitive to the action of these drugs; the most noteworthy being tuberculosis, plague, cholera and the large and varied group of infections caused by Gram negative bacilli* ranging from acute severe infections, such as typhoid fever, to acute and chronic infections by bacteria normally present in the intestines.



Dr. Selman A. Waksman and his colleagues discovered streptomycin in 1944.

Since penicillin was a natural product of certain species of moulds of the genus *Penicillium*, it was only natural to suppose that other equally valuable antibacterial substances were to be found among the numerous metabolic products of plants, fungi and bacteria. Since 1941, scientists all over the world have carried out extensive searches for naturally occurring antibacterial substances, or antibiotics, as they are now called, but although at least several hundreds have been reported the results in general have proved disappointing. Only one antibiotic, streptomycin, discovered in 1944 by Waksman and his students at Rutgers University, New Jersey, in the mould, *Streptomyces griseus*, has so far proved suitable for trial in cases of human infection, other than by surface application. Between the test-tube proof of antibacterial activity and the decision to undertake large-scale production and chemical purification, there are many tests to be passed, since the antibiotic must be shown to possess certain properties among which are the following:

(*a*) the substance should be capable of production in large amounts and should be sufficiently stable to enable at least partial purification to be carried out;
(*b*) partially or completely purified, it should be sufficiently free from toxic properties, to be used at curative levels in man or animals, without risk;
(*c*) its antibacterial action should not be antagonised or rapidly destroyed by body tissues or fluids;
(*d*) it should be capable of producing partial improvement, if not cure, in experimental infections in animals, and, if possible, against organisms not susceptible to the action of sulphonamides or penicillin.

Streptomycin succeeds in satisfying the majority of the above requirements, and while it has certain disadvantages compared with sulphonamides and penicillin, it has the supreme merit of being active, at any rate in the test tube, against most disease-producing bacteria.

Production of streptomycin is a relatively easy matter, though costly, since the liquid culture medium, in addition to glucose and salts, contains meat products in the form of meat extract and peptone. Meat products are both dear and scarce, and the discovery of a cheap synthetic medium giving a good yield of streptomycin is essential if the drug is ever to be available at a reasonable price. Early production was by surface culture in small flat vessels or in milk bottles, partly filled with culture medium and kept at rest in the horizontal position for 8 to 12 days at 27°C. The mould grows as a surface pellicle, and the streptomycin passes into the medium. This is now being replaced by deep fermentation methods (Fig. 1), such as are used extensively in the production of penicillin.† Large tanks containing as much as 10,000 gallons of culture medium through which air is blown continuously are used, so that the mould is continuously agitated and grows densely throughout the medium in short mycelial filaments. The maximum streptomycin yield is obtained in 60 to 90 hours, and the risk of possible contamination with other micro-organisms which would result in the loss of the batch is more than counterbalanced by the economy in time and effort.

Good culture batches yield 200–400 units of streptomycin per cubic centimetre; pure streptomycin base has been assigned the value of 1000 units per milligram. Many batches fall below this standard as is usual in the large-scale production of mould products, because of variation in the mould, difficulty in standardising cultural conditions throughout the growth period, or because of chance contamination by bacteria or other moulds. At the end of the growth period the mould is separated by filtration from the culture medium containing the streptomycin, and the latter is extracted as follows:

(1) The culture filtrate is made acid (to pH 2·0) by adding concentrated hydrochloric acid; charcoal is added, well stirred and then removed, taking with it a number of absorbed impurities.
(2) The clear filtrate is made neutral, and again stirred with charcoal. This time the streptomycin is absorbed by the charcoal which is then removed.
(3) The charcoal with absorbed streptomycin is washed with alcohol and then suspended in two successive lots of methyl alcohol containing hydrochloric acid (Fig. 2). The streptomycin goes into solution in the methyl alcohol and is precipitated out with

* Bacteria are classified by their staining reaction when treated with a basic stain followed by iodine. Those which retain the stain when subsequently treated with alcohol are Gram positive: those which decolourise are Gram negative.

† The deep-tank process for producing penicillin was described in DISCOVERY, 1946, Vol. 7, pp. 163–6.

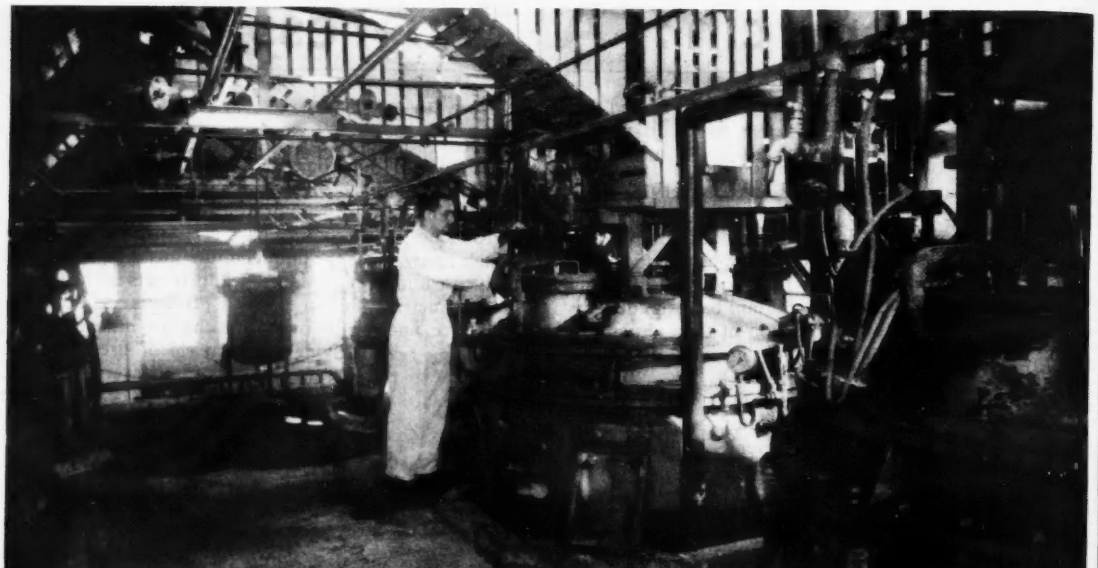


FIG. 1.—Deep fermentation tanks for production of streptomycin as used by Boots Pure Drug Company at Nottingham.

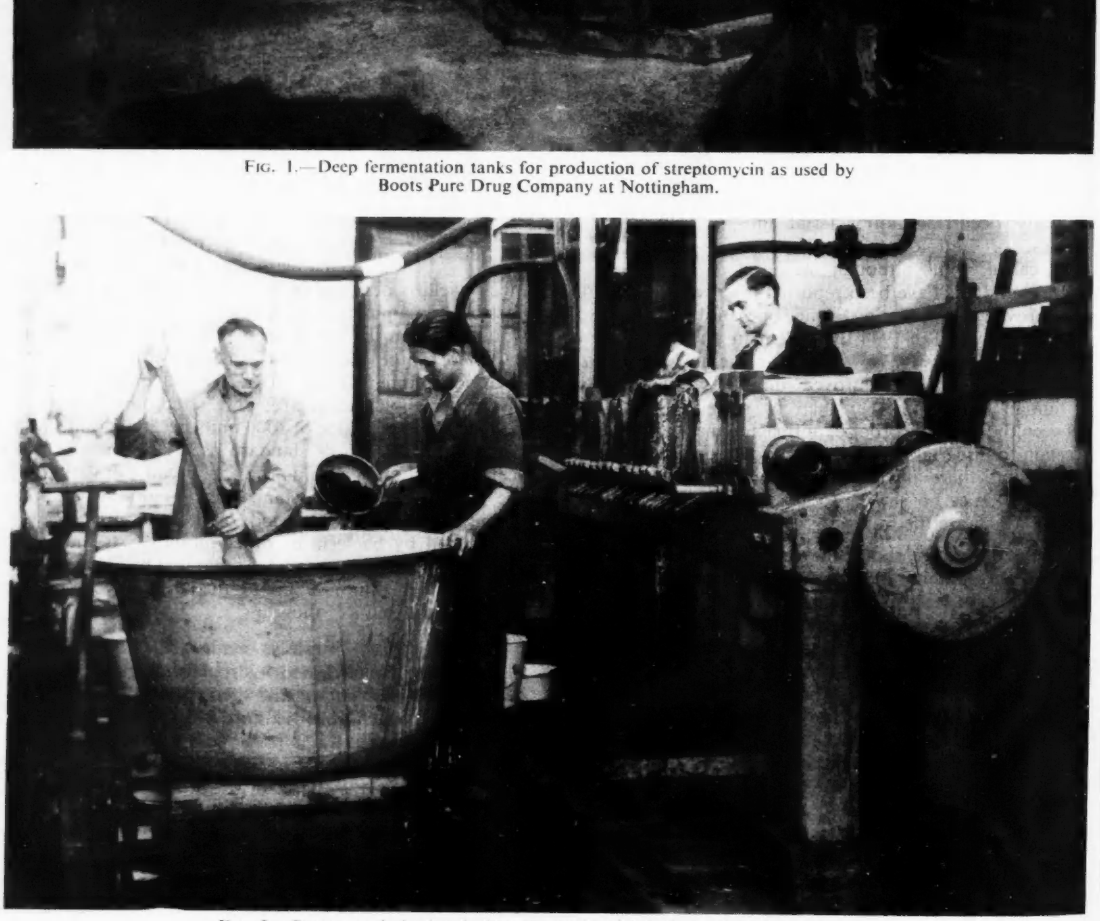


FIG. 2.—Streptomycin is absorbed by charcoal which is then collected by filter press shown on the right. It is then removed from the charcoal by stirring in a tank containing acidified methyl alcohol.

ether and dried to a powder. Yield is about 30–40% of the original activity and the material is about one-third pure.

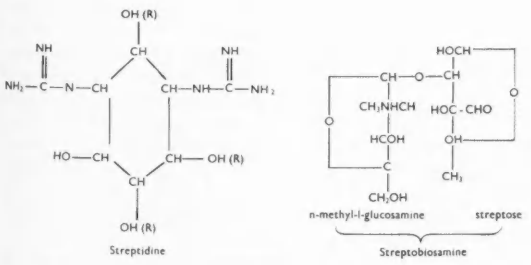
(4) Further purification is carried out by passing the streptomycin through an alumina column, on which it is first absorbed and then removed by washing through with methyl alcohol and collecting the separate washings.

The method as outlined above is more lengthy and has a lower yield than that employed in the case of penicillin. An additional disadvantage is that many batches on partial purification have toxic properties which may be difficult, if not impossible, to remove by further chemical treatment. Recent evidence indicates the presence of at least two streptomycins (there are at least nine penicillins), and should there be others, one possessing toxic properties, it might account for the toxicity of certain batches following purification. Before releasing a batch of streptomycin for clinical use, very careful trials are made to exclude the possibility of its causing toxic effects in the patient. Early batches of streptomycin caused unpleasant local reactions due to a histamine-like substance, and daily injections over many months, as is found necessary in the treatment of tuberculosis, may cause some damage to the auditory nerve with disturbance of equilibrium.

Streptomycin is manufactured in Great Britain by Boots Pure Drug Company, Glaxo Laboratories and Distillers Company, but current production is low in proportion to the needs. A single case of tuberculosis may need 350 grams for a full course. All streptomycin produced in Britain or imported is distributed by the Medical Research Council to six hospitals for clinical trials, and other large hospitals receive smaller amounts. The drug is administered by injection of between 1 and 3 grams daily.

Structure

Chemically, streptomycin is an organic base and has been obtained in the pure state. From the size and complexity of the molecule* it is unlikely that it will be readily synthesised. None of the fractions obtained on hydrolysis of streptomycin possesses antibacterial action.



* Hydrolysed by acid, it yields two basic fractions, a diguanidine base named streptidine, one of the eight meso forms of 1, 3–diguanido–2, 4, 5, 6–tetrahydroxycyclohexane and a nitrogen containing disaccharide named streptobiosamine composed of *n*-methyl-*l*-glucosamine and a sugar streptose. In the streptomycin molecule, streptidine is linked through carbon atom 5 to the first carbon atom of streptose by a glycosidic linkage.

Disease	*Causative organism*	*Results*
1. Tularaemia	Small Gram negative bacillus	*Excellent*, of 67 cases 63 recovered
2. Meningitis (H. influenzae)	Small Gram negative bacillus	*Excellent*, of 100 cases 79 recovered
3. Infection of urinary passages	Gram negative bacilli, mainly of intestinal origin	*Good*, of 398 cases 166 recovered, 141 improved
4. Blood stream infections	Gram negative bacilli	*Good*, of 70 cases 48 recovered or improved
5. Lung infections, acute and chronic	Mainly Gram negative	*Good*, of 44 cases 29 recovered or improved
6. Peritonitis	Gram positive and negative bacteria from the intestine	Probably good, of 53 cases 39 recovered
7. Tuberculosis, all forms	Tubercle bacillus	Palliative effect. Suppressive action with some healing during administration. Disease not eradicated
8. Typhoid, undulant fever, dysentery	Gram negative bacilli	Doubtful if any effect

TABLE I.—RESULTS OF STREPTOMYCIN TREATMENT, BASED ON A REPORT OF 1000 TREATED CASES OF HUMAN INFECTION

Curative Properties

Even for the expert, it is difficult at the moment to obtain a clear picture of the relative merits of streptomycin, and it is very much to the credit of both manufacturers and clinicians that they have aimed from the first at carrying out careful clinical trials and have refrained from presenting over-optimistic reports during their progress. Table I is based on the most important of these studies, a report made by a Commission of the National Research Council of America in 1946 on the experience of fifty-five accredited doctors treating 1000 cases of mixed infections with the drug. Although the drug is active in the test tube and in experimental animals against all the bacteria involved in these 1000 human infections, yet there are only two infections (1, 2) in which it has a distinct success; four forms of infection (3 to 6) in which it has partial success; and four (7, 8) in which its effect is palliative or doubtful. No results, apart from two cases, are yet available for the treatment of plague in humans by streptomycin, but reports in animal experiments are very encouraging.

The two diseases in which streptomycin has been most successful—tularaemia and meningitis, caused by the influenza bacillus (not the causal organism of influenza)—are severe infections, though not important numerically. Tularaemia is uncommon outside America and is transmitted to man by infected rodents (squirrels, rabbits and hares); about 5% of those infected die. The other is a

low-grade form of meningitis found in infants, occurring rarely but constantly in all countries, and which, prior to the introduction of sulphonamides and penicillin, killed 19 out of every 20 children affected. Sulphonamides, penicillin and antisera saved some 60% of these cases in expert hands, but with streptomycin the results should prove very much better.

Of the partial successes, infections of the urinary passages (kidney and bladder) by Gram negative bacilli usually of intestinal origin form a very important group, since it represents a vast amount of chronic ill health in all classes and especially in older age groups. These bacteria, although normally present in the body, are unable to invade and cause inflammation in normal tissues, but often do so when the local or general resistance is reduced in some way. In the past, these cases have often been treated successfully by giving such antiseptics as sulphonamides by mouth, which were then excreted into the urine where they came into contact with the bacteria in the urinary passages. Streptomycin has a similar action, since it too is excreted in the urine, but as with its predecessors, in many cases the inflammation may subside and the bacteria may even disappear completely from the urine, only to reappear there when treatment ceases. Even worse, they may show a steady gain in resistance to the drug during the course of treatment. Nevertheless, streptomycin appears to be the most successful urinary antiseptic at the present day, and deserves wider trial and use in this condition.

Of streptomycin's other partial successes against Gram negative bacteria, in blood-stream infections, lung infections, and peritonitis, it is difficult to give an opinion. Many of these cases have been treated successfully in the past by sulphonamide drugs; and, in the case of peritonitis, with the addition of penicillin. Streptomycin may be superior to both, but we have as yet insufficient information for a reliable comparison.

The treatment of tuberculosis by streptomycin has naturally aroused the most interest, both in the medical and lay mind, since this disease ranks as one of the most widespread and lethal in every community. In England and Wales there are some 60,000 new cases reported each year and over 25,000 deaths from this cause. Moreover, the tubercle bacillus, because of its unusual structure and the peculiar nature of the damage it causes in the tissues, is believed to be less susceptible than are other bacteria to the curative action of chemotherapeutic drugs. Preliminary studies on the treatment of tuberculosis in guinea-pigs by streptomycin, reported as early as 1944 by Feldman and Hinshaw of the Mayo Clinic, Rochester, Minnesota, indicated that the drug had a powerful chemotherapeutic action on the acute lesions produced in guinea-pigs by the injection of living tubercle bacilli and gave hope of a similar result in human infections. Unfortunately, the results reported by Feldman and Hinshaw on 100 cases of human tuberculosis treated in the course of two years are largely disappointing, when analysed.

The results are not easy to summarise since tuberculosis takes many forms according to the type of body tissue attacked and the age and resistance of the patient, and all these factors must influence the patient's prospects of recovery. Nevertheless, they follow a similar pattern. Of 32 cases of progressive tuberculosis of the lung treated, 25 were improved, as shown by regression of the lesions in X-ray pictures; in 12 of these, the tubercular cavities closed and bacteria disappeared from the lung discharge in 13. Six of these cases relapsed on the cessation of treatment and a further course of streptomycin produced an improvement in five of them. Treatment often extended over 3 to 6 months, as much as 360 grams being given in that time.

A very similar picture is obtained with superficial or localised forms of tuberculosis. These are improved and even healed, as shown by closure of ulcers and sinuses, but always with the likelihood of relapse when treatment ceases. Life may be prolonged for many months in cases of tubercular meningitis (normally such cases survive about 3 weeks), but certain nervous disabilities remain and few, if any, can as yet be pronounced permanently cured. As in the case of urinary infections, the bacteria frequently gain in resistance to the drug during treatment (as much as 1000 times), although, fortunately, this does not appear to affect the clinical results. It is only fair to say that the cases of lung tuberculosis chosen for treatment were all severe and had shown no improvement when treated by the usual methods.

Finally, while the concentrations of streptomycin in the blood and tissue fluids are sufficiently high to kill the organisms responsible for typhoid fever, undulant fever, and dysentery, if added to small numbers of these bacteria multiplying in culture medium, yet the drug has very little, if any, action on the course of the diseases they cause in the body.

Limitations of Streptomycin

At the moment it is not easy to give a complete explanation for the numerous failures encountered in streptomycin treatment, although we may gain some knowledge of the factors involved by comparing its action *in the test tube* with that of a more uniformly successful chemotherapeutic agent, such as penicillin. The following are the main points of difference:

(*a*) Unlike penicillin, the amount of streptomycin required to produce death, or even inhibition of the growth, of bacteria depends on the number of bacteria present. An increase in the concentration of bacteria requires an increase in the concentration of streptomycin.

(*b*) Streptomycin has only a suppressive effect on many bacteria such as the Gram negative bacilli. They are not completely killed, but may slowly multiply and finally grow up in the medium having developed a resistance to the streptomycin present. By contrast, most bacterial species are killed off rapidly and completely at effective penicillin concentrations. "Persisters" such as occur in the case of the staphylococcus are weakened in virulence, and drug resistance is not easily acquired by any sensitive species.

(*c*) Streptomycin is a base and in consequence suffers a diminution in antibacterial action as the tissues become more acid. Normal tissues are nearly neutral in reaction, but diseased tissues and their breakdown products, such as pus, are acid. A tenfold increase in hydrogen ion concentration (one pH unit) from neutrality, common in any damaged tissue, may result in an 80% loss in streptomycin activity.

[Continued on p. 20

The Search for New Plastics

PAUL I. SMITH

THE chemist by his experiments in polymer chemistry, the physicist by his knowledge of molecular structure and the technologist by practical application of new methods of processing or shaping, all these specialists are making valuable contributions to an improvement in the properties of the familiar plastics. Meanwhile, scientists concerned with both short-term and long-term research in the chemistry of the long chain molecules are adding new polymers to the range, some of these being discovered as a result of work on other problems, while others are purposeful, planned achievements. Although the accidental discovery cannot be ruled out, there is growing evidence that the chemist by his improved knowledge of the mechanism of polymerisation is approaching the time when molecular architecture will become just as realistic as the architecture concerned with new homes and factories. The ideal aimed at is the making of synthetic plastics to measure so that man-made constructional materials with pre-determined physical and chemical properties will be produced to order.

Methods of obviating some of the shortcomings of plastics are constantly being developed, and particular attention is given to means of widening the scope of plastics so as to increase their usefulness. In general this may be achieved by replacing old resins by new ones and improving the properties of the better-known plastics by physical or chemical modifications of structure. For example, a greatly improved form of regenerated cellulose suitable as yarn and providing satisfactory insulation for wires and sheathing for cables is now being made by giving the molecule an orientation such that the resultant form of cellulose possesses a very high tensile strength and resistance to stretch.

One of the most important methods of chemical modification of existing plastics is afforded by the process of co-polymerisation, i.e. the linking together of two distinct resin-forming chemicals, or monomers, so as to produce a kind of 'partnership' polymer. For instance, when a mixture of vinyl chloride and vinyl acetate is polymerised, the co-polymer, polyvinyl chloride acetate is formed. This is something more than just a mixture of polyvinyl chloride and polyvinyl acetate; the preparation of the co-polymer involves in fact a chemico-physical linking together of the two polymers. Again, styrene and methyl methacrylate, both well-known monomers, can be co-polymerised to obtain a range of new plastics. It is often possible to modify very considerably the properties of a particular plastic, say acrylic resin, by co-polymerisation. Thus, if methyl methacrylate is co-polymerised with the new monomer, diallyl phenyl phosphate, a plastic is produced that is flame-resistant, whereas, of course, the ordinary acrylic resin is inflammable.

The introduction of other radicals or groupings into the cellulose ester type of plastic gives the chemist plenty of scope for producing new materials. In addition to the familiar celluloid and cellulose acetate, and the ethyl and methyl celluloses, we now have the so-called mixed esters, such as cellulose acetate butyrate and cellulose acetate propionate. One type of cellulose acetate butyrate has found many applications where an acetate type of material possessing improved stability and ageing properties is required. Extruded cellulose acetate butyrate has found some use in the U.S.A. for domestic gas-piping instead of metal.

By 'tinkering' with the long chain molecule it is often possible to endow a plastics material with unique properties. In the case of nylon, changes in the nature or proportions of the chemicals used to make nylon salt from which the polyamide is manufactured or alteration in the conditions of polymerisation can lead to major changes in properties. Already a nylon, known technically as N-substituted polyamide, has been produced in the United States and is claimed to have a much higher elasticity than ordinary nylon. New nylon polymers have also been developed for use as moulding powders. These enable resilient, tough and boil-proof articles to be made by injection moulding; and for abrasion-resistant and exceptionally strong cable sheathing and wire covering to be extruded. Also new and offering promise are the nylon-based lacquers and special adhesives which provide a tough coating that offers good protection from abrasion and corrosion.

Melamine and Silicone Plastics

Some of the alternatives to the older types of synthetic resins developed largely during the war years are now receiving considerable attention. Melamine plastics are of special interest as representing an improvement in physical properties over the familiar urea formaldehyde type of resin. Although melamine was first synthesised in the laboratory by Justus von Liebig in 1834, it was put on the shelf as being too difficult and costly to make and apparently of no commercial value. It is only within the last eight years that melamine has become an industrial chemical, and melamine plastics were developed largely during the war years for the production of mouldings possessing the properties (stability, heat-resistance, dielectric strength and high arc resistance) necessary to ensure the proper functioning of aircraft ignition systems in rarefied atmospheres and for use under tropical and also arctic conditions. Other applications of melamine resins include heat- and water-resisting tableware that is tough and durable, buttons that can be laundered without breaking, hard-wearing paints and enamels, and strong adhesives. Melamine plastics, although more expensive than those derived from urea formaldehyde, are definitely superior to them in many applications and offer industry new materials possessing excellent stability and resistance to burning and electric arcs. They are aptly suitable for a large number of applications in the home; such as small switches and circuit breakers, and shatter-proof lighting reflectors.

Some very interesting developments have taken place in silicone plastics, new formulations now being produced for use as lubricating greases and laminating resins. From

this class of compound can be made water-repellent coatings. The chief stumbling block from a commercial angle is the high cost of the intermediate materials. The outstanding heat-resistance of the silicones makes them particularly useful for applications involving exposure to temperature exceeding 300° C. for long periods. The use of silicone fluids as lubricants in high vacuum diffusion pumps operating at 350–435° F. is specially worthy of note. There is no doubt that the extended use of silicone resins as laminating resins for glass fibres will ensure a greater efficiency for many types of electrical equipment, including transformers, motors and condensers, where other insulating materials fail because they cannot withstand high temperatures without breakdown.

Fluorine Plastics

The new fluorine plastics are likely to assume importance where a rigid, tough plastic with exceptional resistance to heat and corrosion is required. The polymers of tetrafluorethylene are so far the most important materials in this field, and they are made by polymerising the gas tetrafluorethylene in the presence of a catalyst so as to produce a solid resin. Although generally classed as a thermo-plastic, polytetrafluorethylene does not melt like polythene but decomposes slowly from about 620° F. It has a lower moisture absorption figure than any known plastic and a far greater resistance to chemicals (except the alkali metals) than the noble metals. The mechanical strength of polytetrafluorethylene is good; in particular it has a high impact strength and retains this from —150° F. to 550° F.

Owing to the high softening point of this fluorine plastics material, moulding and extrusion present certain difficulties. The present method of moulding makes use of a sintering technique familiar to metallurgists but hitherto unknown in the plastics industry.

The most important applications yet found for polytetrafluorethylene are those where its exceptional heat resistance, electrical insulation and chemical inertness can be exploited. It has so far found uses for gaskets and packing materials as well as tubing for chemical processing, and during the war years it was utilised successfully as a wire insulation in jet aircraft.

We are only yet on the fringe of the fluorine plastics, and awaiting chemists are an entirely new range of products, all of which are likely to be typified by varying degrees of heat and chemical resistance. The great inertness of these new plastics suggests to industry many applications where conventional materials are not satisfactory. A glance at the patent literature shows that some interest is being taken in the development of polyvinyl fluoride. This is obtained by heating the gas vinyl fluoride under pressure in the presence of a catalyst.

In face of many sensational claims for new plastics made abroad it might seem as if this country is lagging behind in technological progress. This is far from the truth. The British Plastics Industry is rapidly consolidating its position and apart from concentrating on the supply of materials and finished goods for export, it is devoting a great deal of attention to the development of new uses for familiar plastics as well as producing new materials with specialised applications. Mention might be made here of the wide field of optics, particularly television and photography, now open to the transparent plastics based on special acrylic and styrene resins. This has only been made possible by the perfection of a new British technique of fabrication which enables aspherical as well as spherical lenses to be produced in plastics on a commercial scale.

STREPTOMYCIN: A PROGRESS REPORT—*Contd. from page 18.*

Penicillin, being an acid, is more effective under these conditions.

Lastly, it is never safe to make exact comparisons between test-tube experiments and actual happenings in living tissues, though the former are a useful guide if their limitations are borne in mind. We know as yet relatively little concerning the part played by the body in killing off bacteria in the presence of chemotherapeutic drugs, though experience in other fields teaches us that without a sound general resistance it may be difficult for the tissues to eliminate bacteria completely, even under ideal circumstances. The Gram negative bacilli found in chronic infections of the urinary tract would never have gained a foothold there had it not been for some lack in resistance of the affected tissues, nor does the tubercle bacillus, except through some massive inoculation, invade and cause progressive lesions in the healthy body. In treating such infections we are faced with the fact that the patient's general resistance is certainly impaired, and that until this can be remedied, no form of chemotherapy may be entirely successful.

All the above factors may play a part in reducing the power of streptomycin to produce cure in human infections, but to most investigators it is its action in suppressing rather than killing bacteria which marks it off so sharply from the more successful drugs, such as sulphonamides and penicillin. This suppressive action is very apparent in the studies made by Feldman and Hinshaw on experimental guinea-pig tuberculosis. Although the treated animals remained alive and well and the tubercular processes had healed, it was yet possible to recover virulent tubercle bacilli from the tissues of the majority of the treated animals, showing that the disease was not eliminated. The animal experiments in fact confirm the test-tube findings. A comparison of the known chemotherapeutic agents makes it seem unlikely that a substance whose main action is suppressive rather than lethal can ever be a really effective chemotherapeutic substance. Nevertheless, until a more powerful drug acting on Gram negative and tubercle bacilli is discovered, streptomycin will play a very important part in the treatment of these infections, though it is not the final answer.

(Figs. 1 and 2 are from Topical Press photographs. The photograph on the cover of this issue is by Jean Straker of Photo-Union and shows inoculation of bottles of culture medium with 'streptomycin' spores; reproduced by courtesy of Boots Pure Drug Company.)

An Arrow Poison Saves Lives

TREVOR I. WILLIAMS, B.A., B.Sc., D.Phil.

THE first records of South American arrow poisons date from the early 16th century. The extravagant and thoughtless behaviour of the Spanish *Conquistadores* quickly turned their originally friendly reception into a very hostile one and they became painfully familiar with the native custom of tipping arrows and blowpipe darts with a powerful poison. Europeans found it exceedingly difficult to render the native name of the poison into phonetic equivalents in their own languages, and consequently the early literature refers to it by many different names. Some of the commonest variations are *urari*, *ururara*, *avara*, *worari*, *ourary*, and *uiraery*. The last name was supplied by the great Alexander von Humboldt and as he was, with his brother Wilhelm, one of the founders of modern philology it is probable that *uiraery* is a very close approximation to the old native name. Today, however, the name *curare* is almost universally used for the poison.

The first accounts of curare were supplied by Peter Martyr, an Italian resident at the Spanish court, in his history of the New World, *De orbe novo*. He said quite rightly that the natives poisoned their arrows with juices distilled from various plants. He started also a myth, which persisted for more than two centuries, that the poison was prepared by old women "who are shut in at certain times and furnished with the necessary materials. If the women are not found lying on the ground half dead from the fumes of the poison they are severely punished, and it is thrown away as being valueless." In fact, it is now known that women are carefully kept away when curare is being brewed, because they are believed to render it useless, and that no poisonous fumes are evolved during the process, except possibly carbon monoxide from the charcoal fires over which the vessels are heated.

The effects of poisoning by curare (of which the chief is general paralysis) were vividly described by early explorers. Herrera, for example, reported that the Indians "killed Garcia de Soria with a wound which did not enter more than a half finger deep but, being poisoned, he died in twenty-four hours". Nicolao Monardis, who discovered the phenomenon of fluorescence, wrote that "the wilde people of the Indias annoint their Arrowes with an hearbe made of many poysones, and this Venom is so evill and pernicious that they that bee hurte dieth with great paines and accidentes, and with madness". Humboldt later questioned many Indians who had recovered from curare poisoning received in battle. He reported that they complained of "congestion of the head, vertigo that compelled them to sit down, nausea and vomiting, raging thirst, and a numbness near the site of the wound".

Experience of the poison led naturally to a search for an antidote. Among the substances that have been recommended are sugar, salt, and bile salts. All these have, however, little if any effect and the antidote commonly recommended today is prostigmine, though a mixture of the drugs eserine, atropine and ephedrine is said to be better.

The remarkable properties of curare not unexpectedly resulted in a determined attempt to discover the recipe used for its preparation. For a great many years, however, the natives kept their secret. It was commonly believed that curare was made from several different plants (though the exact species of these were not known) and various poisonous animals such as ants, snakes, and scorpions. For a long time it was not altogether clear whether curare was primarily animal or vegetable in origin.

Not until 1879 was there published a first-hand account of the preparation of curare by the natives. The author was Richard Schomburgk. The chief ingredients proved to be the bark or roots of trees of the *Strychnos* family—the family of which one species, *Strychnos nux vomica*, yields the poison strychnine. Curare is, however, quite different from strychnine in its properties. The material was ground up in a mortar and then placed in a flat earthenware pot made specially for the purpose and destroyed afterwards. About two gallons of water was then added and the mixture was simmered for about twenty-four hours over an open fire. At the end of this time most of the water had evaporated and about a quart of brown liquid, resembling strong black coffee, was left. The liquid was strained into a smaller vessel and exposed to sunlight for about three hours. At the end of this time some slimy juice from a plant known as Muramu was added. This immediately coagulated the poison, turning it into a jelly. After further exposure to sunlight the jelly turned into a hard horny substance. The Indian tested the poison against some lizards which were caught for him. One which was wounded in one of the toes of the hind feet with a needle dipped in poison collapsed after eight minutes and died almost at once. A rat died in three minutes and a fowl in two.

The preparation of curare presents many points of interest to the botanist. The main ingredient is almost always the bark of *Strychnos toxifera* (Fig. 1), but many other species of *Strychnos* are also used. The problem is made more difficult to unravel because different tribes use somewhat different recipes. Nearly two dozen species of *Strychnos* alone are known to be used, including some of the giant bushropes, lianas which are as thick as a man's body and often hundreds of feet in length. Plants of the family *Menispermaceae* are also used as ingredients by many tribes in the preparation of arrow poisons but in general their toxicity is only a fraction of that of the *Strychnos* species.

Chemical Studies on Curare

The chemistry of curare was first investigated just over a century ago but great difficulties were encountered because the product was so variable. The chemical composition of one sample of curare may differ quite considerably from that of another obtained from the same part of South America. Three main types of curare are recognised; these are identified by the type of container in which the natives preserve them. The three types are calabash, pot, and tube curares.

The first chemical analyses were carried out at the

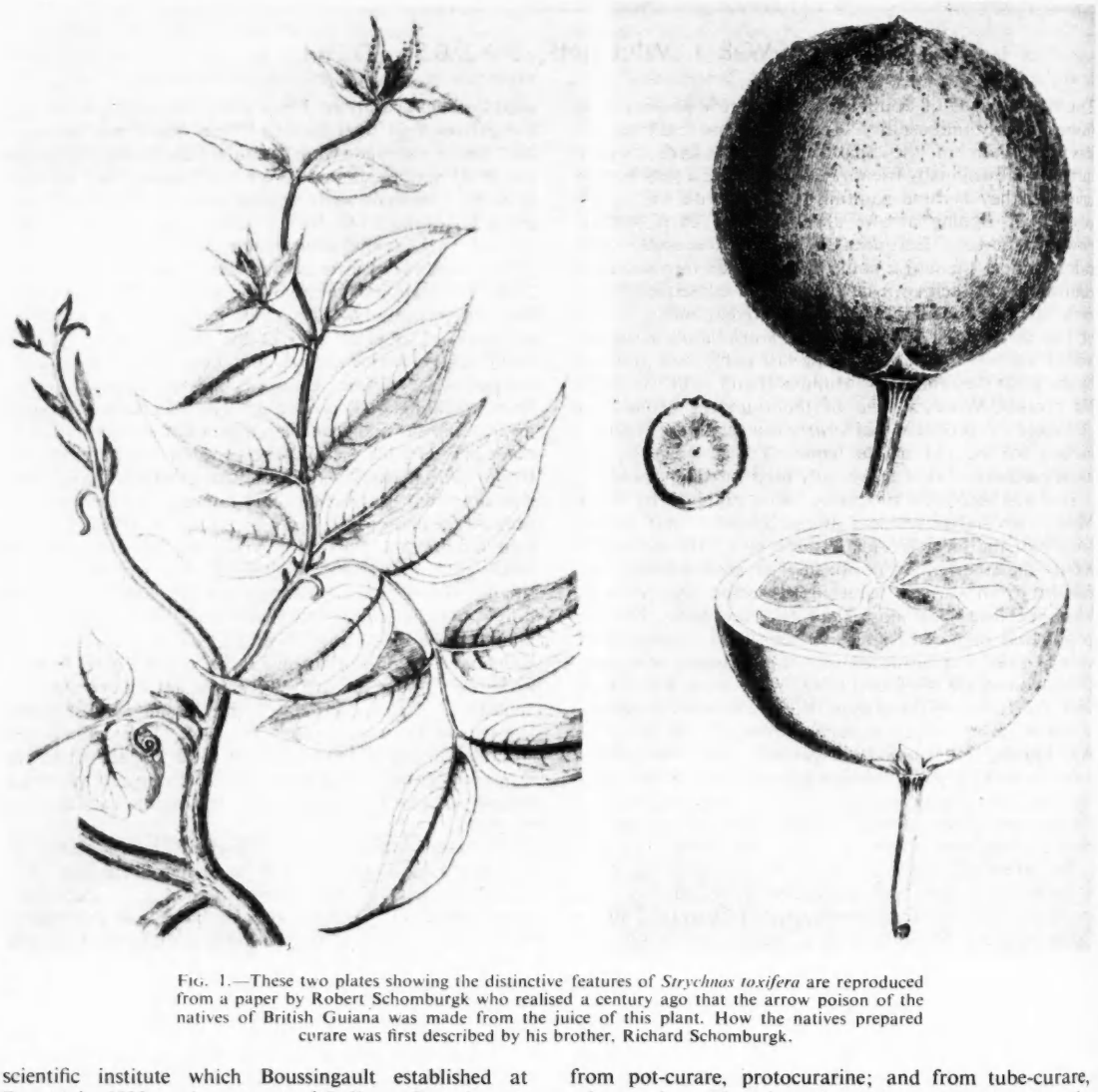


FIG. 1.—These two plates showing the distinctive features of *Strychnos toxifera* are reproduced from a paper by Robert Schomburgk who realised a century ago that the arrow poison of the natives of British Guiana was made from the juice of this plant. How the natives prepared curare was first described by his brother, Richard Schomburgk.

scientific institute which Boussingault established at Bogotá in 1820 at the request of Bolivar. Boussingault and Roulin obtained a 'bitter principle' from crude curare and showed that it was different from the bitter strychnine which Pelletier and Caventou had isolated eight years earlier from *nux vomica*. Pelletier himself investigated curare and confirmed that it contained no strychnine; he found, however, that the isolation of the active principles of curare defeated even his skill in chemical manipulation.

It was, indeed, not until R. Boehm, in 1886, published the first of his series of papers on curare, that any real progress was made, though many organic chemists had tried their strength on the problem. Boehm obtained five distinct alkaloids (basic organic compounds) from curare. From calabash-curare he obtained curarine; from pot-curare, protocurarine; and from tube-curare, tubocurarine. The two other substances which he obtained, 'protocurine' and 'protocuridine', proved to be almost inactive. In 1928 interest in Boehm's work was revived and new methods of organic analysis evolved since his time enabled rapid progress to be made. Today some forty different alkaloids have been identified in the various forms of curare. Their isolation is, however, exceedingly difficult and the only one which has been readily available for experiments is *d*-tubocurarine (the prefix *d* indicates one of its optical properties).

While curare was being examined from the chemical and botanical points of view its effects on animal organisms were also being investigated. The first serious experiments were carried out by de la Condamine, who had investigated the poison at first-hand on the Amazon,

while he was at Cayenne a little before 1813. He continued his work at the University of Leyden; like other research workers and observers he found that curare is a deadly poison when introduced into a wound but almost non-poisonous when taken by mouth. This accounts, of course, for the fact that the Indians come to no harm after eating game killed by curare-tipped arrows. He found that sugar and salt were doubtful antidotes. Humboldt's investigations of the symptoms of curare poisoning have been described above. Sir Benjamin Brodie in 1811 published the very important discovery that animals given doses of curare which would normally prove fatal could be kept alive, and ultimately made to recover, by vigorous artificial respiration. He deduced, quite rightly, that the effect of curare is on the central nervous system, the part of the nervous system which controls voluntary movements. Charles Waterton reported similar effects and carried out some famous experiments on a donkey belonging to Lord Percy. Thanks to artificial respiration the donkey survived for twenty-five years after a massive dose of curare (known to Waterton as Wourali-poison) and in honour of this event the animal was renamed Wouralia. Waterton was outstanding even in a century noted for remarkable characters. He has been described as a wealthy and charming eccentric; he travelled widely, and was the founder of modern taxidermy.

A classic investigation of the pharmacology of curare was begun about 1850 by Claude Bernard. He reported that the poison causes the irritability of nerves to disappear without causing muscles to lose their power of contraction if they are suitably stimulated. Later workers confirmed that curare temporarily paralyses the muscles which control breathing but that life can be maintained by artificial respiration.

It is only comparatively recently that curare has found a use in medicine. Two main difficulties prevented this. First there was great uncertainty about the exact nature of the effects of the drug on the human body. It is now established that although minute doses can cause death—one ounce of the most potent specimens of curare could kill about 500 men—sub-lethal doses properly administered have no permanent ill-effects provided artificial respiration is applied. The second difficulty was that curare varied greatly in its potency to that there was grave risk of overdosage. Today, however, methods of measuring potency have been perfected, and standardised preparations are available commercially.

Some clinical use was made of curare even during the 19th century, chiefly for relieving muscular spasms such as those which occur in tetanus (lockjaw) and epilepsy, but the poison was far too dangerous to be generally accepted. Today, however, curare preparations are rapidly becoming firmly established as an aid to anaesthesia and more than a thousand cases of its successful use have been described. For surgeons, especially those carrying out abdominal operations, the great merit of curare is that it brings about complete muscular relaxation, making manipulation easy, without calling for a great depth of anaesthesia. Deep anaesthesia has been described as more liable to produce shock than the surgical operation itself. A combination of propane and curare approaches the ideal in anaesthesia. Curare has also been used successfully to set fractures and dislocations.

Both because of its curious origin and its remarkable physiological properties curare is a most interesting substance. A complete account of its history, properties and uses—accompanied by a reference to virtually everything that has been written about it from 1516 onwards—will be found in *Curare, its history, nature, and clinical cases*, by A. R. McIntyre (University of Chicago Press, 1947; Cambridge University Press; pp. 240, 27*s*. 6*d*.), on which this account is based.

Volunteers wanted for Cold Research

More volunteers are required for the 'catch-a-cold' experiments which for the past eighteen months have been conducted by the Common Cold Research Unit, set up by the Medical Research Council and the Ministry of Health. This research is being conducted at the Harvard Hospital, Salisbury, and so far about 500 volunteers have taken part.

The research team have a two-fold aim: first, to identify the nature of the virus causing the common cold; and, second, to establish how colds are transmitted from one person to another.

It was emphasised when the investigations started that dramatic or spectacular results could not be expected, but the work is making steady progress. It has established the fact that the type of virus which causes colds is roughly in size 1/10,000th millimetre, about the size of the influenza virus. It is too small to be seen even through the electron microscope and its size has to be estimated through the use of special filters. New facts have been elucidated about the conditions under which the virus preserves its activity. For example, it can withstand freezing at temperatures as low as—70° C. Attempts have been made to grow the virus in the laboratory on eggs, but these efforts have so far proved unsuccessful.

For long-term research of this kind a regular flow of volunteers is imperative if the work is to go on smoothly and without interruption.

Volunteers are accommodated in batches of 24. They live in pairs in complete isolation from other human contact for 10 days. Before the test each volunteer must be free from any symptoms of a cold. They then receive up the nose drops of carefully prepared fluid which in some cases is believed to contain the cold virus. Then a close check is kept to see whether or not they develop colds. On the average, one out of every three volunteers develops a cold; none, however, has been of a serious kind.

There is little difficulty in filling up with volunteer students during university vacations, but for other periods volunteers are harder to get. This year several hundreds are wanted. Normally people of either sex between the ages of 18 and 40 are required. Those volunteering get 10 days free holiday with 3*s*. a day pocket money; they can go for walks or play games.

Those who apply to the Medical Officer, Harvard Hospital, Coombe Road, Salisbury, will receive a special application form, full details of the investigation and dates of forthcoming trials.

Continued from p. 379 of the last issue.]

Man against 'Worms'

GEOFFREY LAPAGE, M.D., M.Sc., F.Z.S.

ALTERNATIVELY the early larval stages may be protected from the world outside the host by becoming parasitic inside another animal, which is usually an animal without a backbone and is often a snail or a blood-sucking insect. This second host of the parasite is called the *intermediate host*, the first host being called the *definitive host*. Sometimes only some of the larval phases are thus protected inside the intermediate host; sometimes all of them are, so that the parasite never enters the world outside a host at all. The two other life histories which we shall consider illustrate this use of an intermediate host.

The Guinea Worm

The first of these is the life history of the guinea worm (*Dracunculus medinensis*), which infects man and some other mammals. It is illustrated by Fig. 5. The fiery serpents mentioned in the Bible were probably guinea worms. The adult guinea worm lives in the tissue under the skin of man and the other animals which it infects, and eventually the adult female approaches the surface of the lower limbs. Often she appears under the skin of the foot or ankle of man and her presence causes the production of a blister full of sterile, yellow fluid. The blister eventually bursts and when the foot or ankle comes in contact with water the womb of the worm bulges out and bursts, setting free into the water large numbers of the first-stage larvae which it contains. This species thus exemplifies the method which some parasites adopt of leaving the host by causing in it damage which liberates the embryos. The first-stage larvae, set free in the water, are hunted out by the intermediate host of the guinea worm, which is the small freshwater crustacean called *Cyclops*. In the body of the crustacean the first-stage larvae of *Dracunculus* grow, and after about ten or twelve days undergo a moult. If now man, or one of the other animals which can be hosts of the guinea worm, swallow water containing the infected *Cyclops*, the infective larvae in the *Cyclops* become parasitic in man and other animals. They migrate through the intestinal walls of the new hosts, and remain in the tissues around the intestine for eight to twelve months, during which time they do not cause symptoms of disease. Becoming mature and mating, the females migrate to the tissues under the skin, where they produce the characteristic blisters.

As many as forty 'fiery serpents' have been found in one person. During the recent war the trouble which they caused made it necessary to invalide out of the Service many African troops infected with them. It is well known that natives remove these roundworms by winding them out, bit by bit, on a stick and this method is still used by modern surgeons, though special surgical operations have been devised for their removal. Because the worms are coiled in the tissues, their removal is always difficult. The infection can be controlled by avoiding water containing the infected *Cyclops* or by sterilisation of the water. This is an example of the principle of attacking the intermediate host, without which the parasite cannot complete its life history. Education of native peoples to do this may, however, be difficult, especially in countries in which the disease is regarded as an affliction sent from Heaven which must not be disturbed by man. The introduction into waters containing *Cyclops* of certain fish which feed on these crustaceans may assist control.

The next and final life history to be considered, illustrated in Fig. 6, is that of Bancroft's filarial worm, and it is an example of the almost complete abandonment by the parasite of the world outside the host. All the phases of the life history except the infective larvae are parasitic inside either the intermediate or the definitive host and even the infective larva enters the external world only for the brief time required for its penetration of human skin. The scientific name of Bancroft's filarial worm is *Wuchereria bancrofti* and it belongs to the section of the roundworms which is called the *Filarioidea*. This name is derived from the Latin word *filum*, a thread, and it indicates that all the roundworms belonging to this section are threadlike in shape. Bancroft's filarial worm causes one of the forms of the human disease called filariasis, which is described below. The adult worms live in the lymphatic system of man. The females produce eggs which have very thin shells and the larvae which develop in them retain these thin shells like diaphanous envelopes around them. They are called *microfilariae* and they appear in the blood circulating at the surface of the human body only at night and especially between the hours of 10 p.m. and 2 a.m. The intermediate hosts of this species are several species of mosquitoes and when these

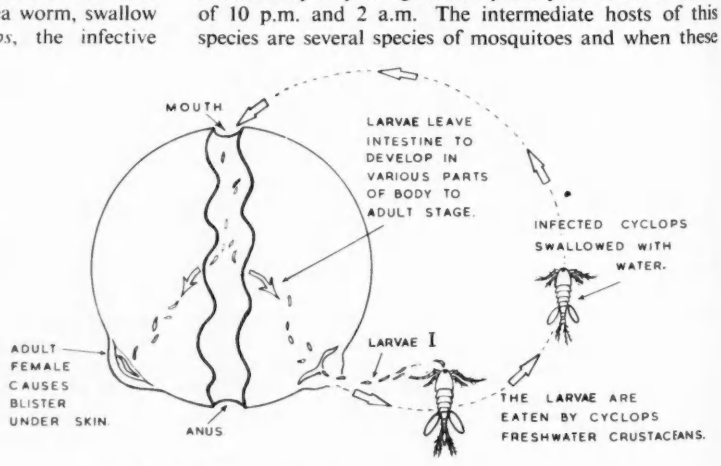

MOUTH
LARVAE LEAVE INTESTINE TO DEVELOP IN VARIOUS PARTS OF BODY TO ADULT STAGE.
INFECTED CYCLOPS SWALLOWED WITH WATER.
ADULT FEMALE CAUSES BLISTER UNDER SKIN.
LARVAE I
ANUS
THE LARVAE ARE EATEN BY CYCLOPS FRESHWATER CRUSTACEANS.

FIG. 5.—Life history of Guinea Worm (*Dracunculus medinensis.*)

mosquitoes suck up human blood containing the microfilarial larvae, these larvae penetrate into the muscles in the thorax of the mosquito and there, in some ten to eleven days, become the infective larvae. The infective larvae migrate (just as the infective stages of the malarial parasites do) to the mouth parts of the mosquito. When the mosquito again bites a man these larvae break their way out of the proboscis of the mosquito and, like the infective larvae of the hookworms, bore their way through the human skin, to grow up in the man thus infected into the adult again. The infective larvae are not, it will be observed, injected by the mosquito into human blood, as malarial parasites are.

We are now in a position to understand better the diseases caused by parasitic nematodes. Limitations of space will not, however, allow us to do more than add to the facts already given a few brief notes about two of the most important human diseases caused by parasitic nematodes.

Hookworm disease

The two most important species of hookworms which are parasitic in man are *Ancylostoma duodenale*, the Old World hookworm, and *Necator americanus*, which has been picturesquely called the 'American murderer'. *Ancylostoma duodenale* was probably known to the Egyptians as early as 1600 B.C. The Ebers' papyrus of that date probably refers to this species. The skin-penetrating habit of its infective larvae was discovered in Egypt by Looss in 1897, when he accidentally infected himself with this species by placing some of its infective larvae on his skin. Later he worked out the migration of the larvae by studying *Ancylostoma caninum* of the dog. *Ancylostoma duodenale* occurs chiefly in southern Europe, and along the north coast of Africa, in northern India, northern China and in Japan; but it has been found in Australian aborigines and had been recently taken by the travels of infected people to southern India, Burma, the Malay Archipelago, the Netherlands Indies, the south Pacific islands and also Portuguese West Africa. *Necator americanus* is widely distributed in the southern United States and in central and northern South America; it also occurs in central and South Africa and in southern Asia, Melanesia and Polynesia.

The name 'American hookworm' is thus not a good one. Some authorities think that *Necator americanus* was originally brought to the United States by native labour imported from Africa. The distribution of both these roundworms will depend, of course, upon the temperature and humidity of the soil, because the non-parasitic first three larval stages must develop in the soil, and they cannot do this unless the soil offers the ranges of warmth and humidity in which their development can occur. For this reason hookworms are rare in temperate or northern countries, although there they may persist in favourable localities, such as in mines or tunnels, where their larvae may be protected from the effects of the climate. For this reason *Ancylostoma duodenale* used to be called the 'miner's worm'. It caused serious disease of German miners in the Ruhr and elsewhere, and has been found among miners in Cornwall. It has now been eradicated from most

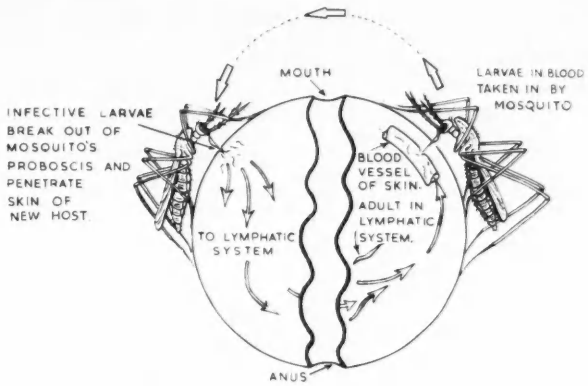

MOUTH
LARVAE IN BLOOD TAKEN IN BY MOSQUITO
INFECTIVE LARVAE BREAK OUT OF MOSQUITO'S PROBOSCIS AND PENETRATE SKIN OF NEW HOST
BLOOD VESSEL OF SKIN.
ADULT IN LYMPHATIC SYSTEM.
TO LYMPHATIC SYSTEM
ANUS

FIG. 6.—Life history of Bancroft's filarial worm (*Wuchereria bancrofti*).

European mines, but German medical men are concerned lest post-war conditions should allow hookworm disease to reappear in German mines. Russian medical men are energetically combating it on the tea plantations of Georgia. The first signs of infection by the hookworm's skin-penetrating larvae are intense itching called 'ground itch' at the place where the larvae penetrate the skin. The skin swells and vesicles form on it. Often the part affected is the skin of the feet and ankles, because natives work in the damp, warm soil of plantations, etc., with bare feet and legs. Infection may, however, occur without this kind of dermatitis. It is when the hookworm larvae reach the small intestine and there grow up into the sexually mature adults that the most severe damage is done. The adult hookworms have bell-shaped mouths provided with teeth with which they suck in the lining of the intestine. They bore their way in until they reach small arteries. Experimental work on the hookworms of dogs has shown that these roundworms suck arterial blood only and that they soon abandon one artery for another, leaving behind them bleeding points which increase the loss of blood. It has been estimated that a single human hookworm, even when it has been parasitic in man for months or even years, can remove at least half a cubic centimetre of blood each day. This means that 700 hookworms could remove rather more than half a pint of blood each day. American workers have estimated that children in some parts of the United States may harbour from one to three thousand hookworms and they regard one to five hundred of them as a moderate infestation. It is not surprising that the disease is a very serious one and that anaemia is its outstanding symptom. The anaemia can be cured by the administration of iron, and the hookworms can be killed by drugs which must, however, be used with great care, because they are themselves severe poisons.

The problem of control of hookworm infestation of man is a vast and difficult one. The disease depends entirely upon the habits and customs of the people who suffer from it. If sanitation and hygiene were efficient enough and if the people's habits conformed to the relatively simple rules laid down by those who seek to control the disease, infestation with hookworms would be greatly reduced. Unfortunately it is one thing to plan and build,

often at great public expense, adequate sanitary installations, and quite another thing to persuade the people for whose benefit they are provided to use them intelligently. Religious customs and traditional practices also interfere with attempts to stamp out this terrible scourge. The fact remains, however, that the most effective remedy for it would be the adoption by the peoples concerned of ordinary civilised sanitary habits.

Filariasis

There are various forms of filariasis due to various species of roundworms, but one of the most important is the form caused by Bancroft's filarial worm, *Wuchereria bancrofti*, whose life history has been considered above. This form of filariasis was known to the Hindus in 600 B.C. and to the early Persian physicians. The parasite is indigenous in practically all the warm regions of the world. In the Americas it is found in the Antilles and on the northern coast of South America; in Africa, on the north coast and in the central tropical belt; in Asia, in Arabia. It is common in India, Burma, Japan, China and down through Indo-China to the Philippines, the Dutch East Indies, north-eastern Australia and Micronesia. It is therefore common throughout the south Pacific area where Allied troops operated in the recent war and became infected with this and other filarioid nematodes.

It is important to realise that infection of man with Bancroft's filarial worm does not necessarily by itself produce disease. Some experts with wide experience state, in fact, that most people who are infected do not show any symptoms. In other individuals symptoms may not appear for a year or even longer after infection. The precise method by which the filariae cause the symptoms, which may appear in some people, is still disputed; but the symptoms shown are mainly the result of damage done to the lymphatic system. The symptoms which ultimately appear are due to blocking of the lymph flow to the part of the body affected, so that the lymph vessels behind the block dilate and lymph exudes into the surrounding tissues. These tissues, therefore, slowly swell up and the irritation caused results in the formation of much new tissue. Ultimately the enormous enlargement of the affected part of the body, which is called elephantiasis, may result.

Filariasis is treated with compounds of antimony, while surgical operations may relieve greatly the sufferings of people afflicted by elephantiasis. Control of the infection follows the principle of attacking the intermediate host upon which the parasitic nematode depends. Until recently control of mosquitoes was less successful than it nowadays is. The discovery of new and remarkably effective insecticides, such as DDT and Gammexane, and the enormous advances which have been made during the recent war in our knowledge of mosquito control, will probably give us considerable control over all insects which transmit disease. The control of filariasis is, however, not made easier by the fact that infected persons may not show any symptoms of the disease and thus may, quite unconsciously, provide microfilariae in their blood which infect mosquitoes by which the disease is transmitted to other people. Our knowledge of methods by which infection with this and other parasitic animals, which may be present in the body without causing symptoms, is, however, increasing. The problem presented by these unconscious sources of infection is being energetically investigated.

Evolution of specialised parasites

A final note may be added on the complex question of host specificity. Roundworms are, generally speaking, confined relatively rigidly to certain species of host only, or only to certain hosts and their near relations. This probably means that they have been parasitic for a very long time and have gradually become adapted to certain hosts only and cannot now live in others. The human hookworm (*Ancylostoma duodenale*), for example, is practically confined to man. The other common human hookworm (*Necator americanus*) is less rigidly host-specific, for it has been found in monkeys, the rhinoceros, the pangolin and in one rodent; and it can, under experimental conditions, develop in dogs and cats. *Ancylostoma caninum* is confined to dogs and cats, although it has been found once in man in the Philippine Islands. Similarly some of the roundworms parasitic in the alimentary canals of sheep cannot live in cattle or horses, so that cattle and horses can be used to graze over pastures infected with the larvae of these species, so that they will eat and kill them and the pastures will be made safer for sheep.

Most interesting of all from the physiological point of view is the fact that the large roundworm of man, *Ascaris lumbricoides*, cannot be distinguished structurally from *Ascaris lumbricoides* of the pig; yet when the Japanese worker Koino swallowed eggs of *A. lumbricoides*, this worm did not develop to maturity in him; it caused only respiratory symptoms due to the presence in his lungs of the larvae, which were able to develop thus far. Normally the converse is also true. The human strain of *A. lumbricoides* will not normally develop in pigs. Another Japanese worker, Hiraishi, has, however, shown that it will develop to maturity in pigs, provided that the resistance of the pigs has been sufficiently lowered by a diet deficient in vitamin A; and Ackert and his American colleagues claim that the human strain will cause respiratory symptoms in pigs, similar to those caused in Koino by the pig strain. There are other examples of this interesting physiological adaptation of structurally indistinguishable strains of the same parasite to different animals; in some instances the age of the animal considered must also be taken into account, young animals being in general more susceptible to infection than older ones. The general condition of the animal, which depends largely upon its diet and perhaps especially upon its intake of certain vitamins and of iron and perhaps other minerals, is also an important factor in this question, as it is, indeed, in the consideration of all kinds of infection. In the tropics, for instance, the widespread malnutrition which Sir Leonard Rogers and Sir John Megaw in their standard work, *Tropical Medicine*, consider to be one of the most important underlying causes of tropical disease, must obviously affect profoundly the incidence of diseases due to parasitic worms. It is impossible in the space available to discuss this complex question further, but its great epidemiological importance will be evident.

Senses of the Skin

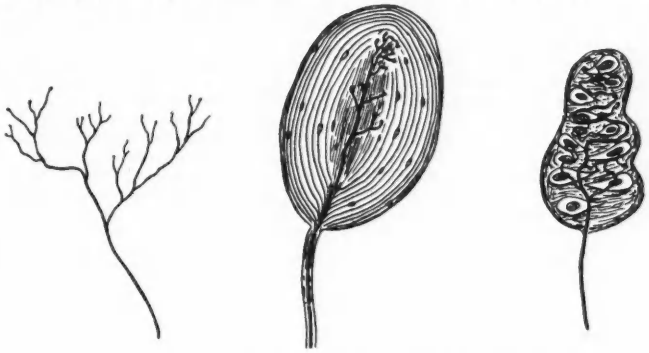
If you stick a pin into somebody, he'll probably jump and cry out. But if the pin is stuck into some parts of the skin it may not be noticed. So the skin is not the same everywhere in its capacity to be affected by a pin-prick. (If you want to test this you had probably better get somebody to stick pins into *you*.)

When the pin is felt, it causes a feeling of pain. But you can feel other things with your skin. Touch is obvious. Your sense of touch enables you to feel the shapes of things even if you are in the dark; and the ability to feel shapes also varies with different parts of your skin. Your finger-tips, for example, are much more sensitive than your back.

You can test this. Take a pair of dividers and see if somebody with his eyes closed can tell, when you touch him with them, whether there are two points or only one. You can vary the distance the points are apart. You'll find that they have to be very far apart for them to be definitely distinguished as two points by the skin on the back. You can find out for yourself about other parts of the skin. (When you do this experiment, touch the person with only *one* point sometimes, to make sure he isn't cheating.)

You can do another experiment with touch if you take a stiff bristle (say, from a scrubbing brush) and fix it to a match stick; split the end of the match with a knife and fix the bristle in the split. The match is used as a handle, and the point of the bristle can test whether a person can feel a gentle touch at a single point. Draw a square, with sides of about 3 centimetres, in ink on the back of somebody's hand; then make him say, with his eyes shut, whenever he can feel anything touching his hand. If you touch the skin in the square lightly with the bristle you'll probably find that most points in the square are sensitive to touch. You can mark the *in*sensitive spots with ink; in one experiment I did there were only three.

Apart from pain and touch you can also detect heat and cold with your skin. To test this you need a metal rod, perhaps a centimetre across. One end must be filed so as to leave a knob sticking out with a flat surface about one millimetre across. To test for sensitivity to cold you can cool the rod down by putting it in water with ice in it. (If you use something smaller than a metal rod, such as a nail, it very soon gets warm again, which makes the experiment more difficult to do). When the rod is cool, test for sensitivity to cold within a square area of skin, just as you did with the bristle when you tested touch sense. The person tested should shut his eyes, so as to concentrate better, and say 'yes' when he feels a cold sensation, and 'no' when he feels only a touch sensation. You can mark the 'cold spots' in ink as before.



Types of touch detector in the skin, much enlarged (after a drawing in "Tissues of the Body", by Prof. W. E. Le Gros Clark, O.U.P. 1939).

You can learn something more about your 'temperature sense' from a different kind of experiment. Put your right hand in hot water for a minute, and at the same time your left hand in cold. Then put both hands in some tepid water. Your right hand will feel cold in the tepid water, but your left hand will feel hot. This is an example of an important fact: our senses tell us about the *differences* between things—whether something is hotter or colder than something else, brighter or darker and so on. So to get an accurate indicator of temperature we use a thermometer, because its reading is not affected by what has happened to it before.

These are all the experiments I can suggest on feeling with the skin. They are quite simple, but you must not think you can do them without any difficulty at all. All experimental work has its difficulties, and part of the fun is overcoming them. Try and see.

Meanwhile I must give you some kind of explanation of the results you get from these experiments. You'll have to take it on trust, because rather elaborate apparatus is needed to test it. If you take a piece of human skin and prepare it suitably you can study its structure under the microscope. This enables you to see things too small for the naked eye. Among the various structures in the skin you find a number of different structures connected to nerves. (I will write about nerves another time.) Some of these structures are illustrated above. One kind is responsible for the feeling of cold when something cold touches the skin, another for pain, and so on. And this is why these different sensations are localised: you can only feel pain where there is a pain organ, and there is only a limited number of them, varying in different parts of the skin. ANTHONY BARNETT.

The Bookshelf

Insect Natural History. By A. D. Imms. (Vol. 8 of "The New Naturalist" series, Collins, London, 1947; pp. 317, 16*s*.)

"INSECT NATURAL HISTORY" is the eighth volume in "The New Naturalist" series and probably none of the previous volumes shows so well what the publishers intend by their title for this fine new series. Here is displayed, for the first time on such a scale and from the pen of such an authority, the entire background of a vast subject, a whole slice, in fact, of that most popular of all the sciences . . . Natural History. The transition, moreover, from the Natural History of the older workers, those indefatigable amateurs of the eighteenth and nineteenth centuries, to the new scientific attitude which is covered by the word 'ecology', used in its widest sense, is carried a stage further with this straightforward, scientifically accurate, and yet completely readable account of the insect world. For although, as the publishers' note observes, some special groups such as the butterflies are already covered by volumes in the same series, this is none the less a general introductory volume, not merely to the insects as such, but also to the whole study of the Insecta as a part of our natural fauna. And though this volume is designed to fit into the scheme on which the whole series is based, it will certainly be in great demand among people who wish merely "to know more about insects".

To the entomologist, the name of A. D. Imms has already long been known as the

author of the rather forbidding standard work *A General Text-book on Entomology*. But even the most enthusiastic student of this, or of his later *Recent Advances in Entomology*, could scarcely have foreseen in their dry and academic pages the author of so charming a text as we have here. That such a work from Dr. Imms would be accurate goes without saying, for there is probably no one better qualified to write of the biological and technical aspects of his subject; but many of the delightful turns of phrase which add character to this book will come as a pleasant shock to those well acquainted with the former works.

Glancing through this book, noting the chapter headings and finding with what completeness the subject is covered, one is astonished that the author has compressed his material into less than three hundred pages of text. Moreover, although each chapter deals with a different aspect of the subject, the total number of insect species described fully enough for recognition in the field is very considerable, and these textual descriptions are borne out by altogether exceptional illustrations. One has come to expect an extremely high standard in the volumes of this series, but it is probably safe to say that no book on this subject has been so brilliantly illustrated. The numerous plates of direct colour photographs, as well as the black and white plates which speak for themselves, are backed up by line drawings in the text which are themselves exceptionally good; and the whole work shows a very notable degree of co-operation between the author and his illustrators.

The majority of the colour plates are the work of Mr. S. Beaufoy, whose superb colour photographs were a feature of E. B. Ford's volume on *Butterflies* in this same series. A new system of numbering the plates, and notes on the methods used to secure some of the photographs (e.g., by 'etherisation' or 'temperature control'), are further evidence of the care which author, illustrators and editors have put into this remarkable book.

In place of the usual bibliography, there is an extremely well-conceived 'Documentary Appendix', a sort of critical reference list; another appendix gives typical distribution maps for six species of insects in Britain; and there is a good index. If anything is missing, it is perhaps some sort of schematic diagram of the relationships of the various orders within the Insecta, giving at a glance the details admirably set out on pages 32 and 33 of the text.

To choose any one chapter can be only a personal matter, in a book wherein so great a part of the text will be new material to the vast majority of readers. Perhaps the most fascinating are those on 'Biological Control' (containing a complete and practical account of how to control 'White-fly' in your greenhouse) and on 'Aquatic Insect Life', a fascinatingly detailed description of the means whereby these creatures survive in their un-natural environment.

If, in years to come, historians of Natural History in Britain find a sudden concentration of interest on the Phylum Insecta, dating from 1947, they will safely be able to lay the blame at the door of A. D. Imms, his illustrators and publishers.

P. B. C.

The Chemical Society 1841–1941. By Tom Sidney Moore and James Charles Philip. (Chemical Society, London, 1947; pp. 236, 12*s*. 6*d*.)

British Chemists. Edited by Alexander Findlay and William Hobson Mills. (Chemical Society, London, 1947; pp. 431, 18*s*.)

THESE two works, appearing on the occasion of the Centenary Celebrations of the Chemical Society, afford compelling and attractive evidence of the massive progress of that science in Great Britain. They are, moreover, invaluable to the historian of science, embodying as they do that personal knowledge that makes history live. An account of the history of the Chemical Society up to 1891 was published in 1896, but the present volume gives a much fuller and more informative account of the first fifty years of its work, followed by a history of the last fifty years such as cannot be found elsewhere. It records not so much the scientific discoveries of its members as the part they played in the direction of the organisation and thought of British Chemistry. Such a forceful personality as H. E. Armstrong, whose scientific work occupies but small space in the living science of today, was enormously influential in the councils of his time and deserves the record that he here receives.

It is well to be reminded of the enormous advance that British Chemistry has made since its Jubilee. The eighties and early nineties were a stagnant period, as Armstrong so forcibly reminded the men of his time. The later nineties showed new life, with the work of Rayleigh, Ramsay, Travers, Dewar and their schools; and thenceforward British Chemistry advanced with increasing acceleration, until in the last decade the work of British chemists has been excelled by that of no other country. This advance called for a reorganisation of the Chemical Society, but owing to the strong conservatism of the Victorians who controlled its Council little was done until the years between the wars. In the twenties a decrease of membership demonstrated the need, and notable changes were brought about in the years round 1930. In these years the Society extended its activities to the provinces, initiated organised discussions, and brought about closer co-operation with the Institute of Chemistry and the Society of Chemical Industry. These measures have proved a notable success and the society has never enjoyed a greater popularity nor given greater service than at the present time.

The second volume, *British Chemists*, consists of memoirs of some of the more distinguished exponents of the science who have died since the outbreak of the first World War: some of these memoirs have been specially written for this volume; others have been reprinted with more or less modification from obituary notices in the journal of the Chemical Society. The men commemorated are Armstrong, Meldola, Dixon, Crookes, Ramsay, Dewar, A. G. Perkin, W. H. Perkin, Jun., Green, Harden, Pope, Morgan, Lapworth, J. F. Thorpe, Lowry and Barger, a list which will serve to remind us of the calibre of the generation that has passed. It is impossible here to mention their individual work, but their lives, written always with the personal touch of one who knew the man, afford not only an admirable history of a great age of Chemical Science, but material for a survey of the temperament and qualities of the scientific men whose labours have had such influence upon our present lives and their uncertain future.

F. S. T.

The Common Sense of the Exact Sciences. By William Kingdon Clifford. Edited and with a preface by Karl Pearson, newly edited and with an introduction by James R. Newman. Preface by Bertrand Russell. (Alfred A. Knopf, New York, 1946; Sigma Books Ltd., London, 1947; 249 pp., 15*s*.)

W. K. CLIFFORD (1845–79) was a gifted mathematician and mathematical philosopher, one of the most original minds of his time. He was also a brilliant and persistent populariser of mathematics. The book which is here reprinted was left in an unfinished state at his death; the version which we have was edited by Karl Pearson—in fact a good deal of it is entirely Pearson, writing what he thought Clifford would have written.

Clifford originally planned to call the book *The First Principles of the Mathematical Science Explained to the Non-Mathematical*, only adopting the present title shortly before his death. And indeed the original title would have been much more appropriate, for the book is almost entirely concerned with pure mathematics except for a final chapter on motion. It is in no sense a course of mathematics. Rather it is an attempt to show the non-mathematician how a mathematician works, what sort of concepts he is concerned with, what are the basic principles on which he builds his mathematical system, with some glimpses here and there of how the building is carried on.

And Clifford certainly knew all the tricks and dodges for explaining lucidly the essence of mathematical thought. The mathematician reading the work will at times be lost in admiration at the facility with which knotty points are explained. The reader who has had at school one of those deadly dull mathematical educations, which provide all the mathematical technique accompanied by hardly a hint as to what the subject is really about, will find no difficulty in reading the book and will discover a new and warm glow spreading over the arid vista of his past mathematical life. The truly lay reader whose mathematics scarce extends beyond arithmetic will fare less well—for, though Clifford starts with conceptions well within the ken of such a person, he moves too fast and is soon out of reach.

It is indeed rather difficult to know to just what class of modern reader the

reprint of this book is addressed. It is, after all, an explanation of the foundation of mathematics for the layman. But mathematics has not stood still in seventy years, and the foundations are very different from what they were then. Thus the long discussion of 'quantity' has been entirely superseded by the modern theory of real numbers, and the reader, hardly warned by the editors' too sparse footnotes, is likely to be completely misled as to the nature of this part of modern mathematics. Similarly, historical development has since Clifford's time entirely changed the relative importance of some branches of mathematics. The layman is likely to be very much deceived by the prominence given to quaternions and screws. And to take a trivial example, the statement that 'logarithms to the base 10 are now used in all but the simplest calculations' looks very foolish in the days of ENIAC; it should not have been allowed to pass without an editorial footnote. These are just some of the snags in the path of the lay reader of the book.

To the historian of science this reprint, like almost any reprint of a classic, will be most welcome—for it is a key work in the history of the popularisation of science. In general it is not a key work for the history of science itself, but there is one remarkable section on the bending of space that reads like an anticipation of general relativity. In it Clifford is considering the geometry of the real universe, or more precisely the possible geometries of the real universe. He does not in fact do anything which can validly be called an anticipation of relativity theory, but his conceptions are so much wider than those of his contemporaries that they provide a mode of thought into which relativity will fit with ease. And the methods which he uses can well be employed by those who try to put over relativity in non-technical language.

But perhaps the person who can benefit most from the book is the conscientious school teacher. If he uses it as a source for ideas about teaching methods, but at the same time employs his own mathematical knowledge to make the corrections required by the passage of time, then indeed he should be well on the way to becoming a much better teacher.

S. LILLEY.

Nuclear Physics in Photographs. By C. F. Powell and G. P. S. Occhialini. (Oxford University Press, 1947; pp. 124, 18*s*.)

THIS book gives an admirable account of the wealth of information obtained by the direct recording method of atomic particle tracks in photographic emulsions. This elementary, but concise text deals with some of the basic features of nuclear physics and the photographic technique applied. It will be intelligible to most scientifically minded readers. No layman who has studied this book should further complain that he could not grasp the basic ideas of subatomic particles on the grounds that nobody has ever seen alpha particles, protons, deuterons, etc. It is true that these particles cannot be made visible. However, their paths, their individual reactions during their passage through photographic emulsions and their behaviour in collisions with other particles are made visible in this book by a series of brilliant photomicrographs taken from photographic emulsions.

The book presents an atlas of atomic particle, meson and fission tracks with explanatory captions below each plate, and it will also be of great interest to physicists and teachers. For them a more detailed, but elementary treatment of some collision processes, such as proton-proton, deuteron-proton and alpha-proton collisions is given in the appendix. Other sections in the appendix deal with interpretations of some nuclear disintegration experiments, determination of the energy of fast neutrons, methods of processing the emulsions, and range-energy relations.

It is the authors' wish to stimulate enthusiastic students of nuclear physics to apply the photographic method of recording particle tracks, because of its simplicity and its wide scope. Not only the authors, but also the publishers should be congratulated on the excellent production of the book and in particular the reproduction of the photomicrographs.

R. H. HERZ.

Aerodynamics. By L. R. Parkinson. (Macmillan, New York and London, 1947; pp. 112, 11*s*.)

IN the U.S. the study of aeronautics is included in the curriculum of many high schools. This fact can be the only explanation for the increasing number of books such as the one under review, which are being published over there. The treatment of the subject matter is clear, but it is certainly too simple to fulfil the claims made that "it has been written especially for members of design departments, not specially trained in aeronautics".

The contents cover all the main aspects of aeroplane flight, starting off with the atmosphere, air in motion, Reynolds number, and even a brief mention of the difficult conception of circulation. Then follows a discussion of lift and drag of aerofoils, including a useful review of American sections, together with lift-increasing devices, which leads to consideration of aircraft performance and stability. Propellers are dealt with in a short chapter, and finally wind tunnels are quite well described. This is a formidable list for 100 pages, so that it is not surprising that the treatment of many important points is very sketchy. Style, too, is a trifle American—to convince us that some air sticks to the surface, we are told that "California sand remained on an airplane when it arrived in New York at the completion of a record-breaking transcontinental flight"!

One serious error occurs on page 29. Pitching moment must be a force times a length, but the length term, taken as the wing chord, is omitted in the expression given.

Within its limitations this volume does contain much useful information, in a form easily understood by the non-mathematical reader, but it should not be thought of as an addition to the number of comprehensive text-books on aerodynamics which already exist. J. B.

The Soil and the Plant. By Ernest Vanstone. (Macmillan, London, 1947; pp. 71, 4*s*. 6*d*.)

Fertilisers and Manures. By Ernest Vanstone. (Macmillan, London, 1947; pp. 79, 4*s*. 6*d*.)

EACH of these short books is described as a simple introduction for students in farm institutes and agricultural colleges. It is probably unfair criticism, therefore, to say that the books strike an over-simplified note, particularly the second book on fertilisers and manures.

To the general reader *The Soil and the Plant* will be of much more solid value although it is the shorter book. In 71 pages the elementary groundwork of soil fertility and plant-growth is covered clearly, and the author has included a considerable amount of recent material. In the past six or seven years orthodox ideas about soil fertility and plant nutrition have widened, and Dr. Vanstone's simple presentation covers these changes. For example, the chapter on soil analysis stresses the limitations of the standard laboratory method, an advance on most pre-war introductory books which led farmers to believe that soil analysis was a foolproof solution to their problems. Indeed, this book is so clear and concise that one is left with the feeling that any worth-while student must wish that the author had gone a little farther with some of the more fascinating sections; however, as late Head of the Chemistry Department at the Seale-Hayne College, Dr. Vanstone should know, better than most, how much students need to absorb and, perhaps more important, how much they can absorb.

Fertilisers and Manures is less satisfactory because it deals with a subject more difficult to handle briefly, a subject in which over-simplification has long been a curse. The author is apparently forced to say shat "superphosphate is an acid substance like sulphuric acid"—true enough in a limited sense but surely appallingly misleading to the beginners to whom the book is addressed. No attempt is made to explain (or apologise for?) our illogical fertiliser terminology, so that on page 14 phosphoric acid is P_2O_5 and on page 17 it is H_3PO_4. This anomaly is certainly not the author's fault but to ignore it is bound to confuse the discerning student-reader. The manufacture of compound fertilisers is discussed without reference to the major problem of 'setting' and the necessity for conditioning processes or granulation to overcome it; also, out-of-date examples of prices for common fertilisers are given, so that this 1947 book is as commercially misleading as standard pre-war books. This is regrettable for the student who later becomes a buyer will suspect that he is being exploited. It is, for example, many years since superphosphate was £3 a ton, and at nearly twice this figure it is a state-subsidised product today. The figure of 10*s*. per ton given as the 1939 cost for mixing and bagging compound fertilisers is a most dubious figure even for 1939. D. P. HOPKINS.

Far and Near

Science and Productivity

THE Government aims to bring science more closely to bear on current problems of industrial production with the setting up of the Committee on Industrial Productivity, whose formation was announced in Parliament on December 18. Sir Henry Tizard presides over the new committee whose activities will supplement those of the Advisory Council on Scientific Policy established early last year (see DISCOVERY, Vol. 8, p. 95). Its work will be conducted through a number of panels. The formation of four panels has already been announced and these will deal with the following matters: *Technology and Operational Research* (Chairman, Sir William Stanier); *Substitutes for Imported Materials* (Prof. S. Zuckerman); *Human Factors Affecting Productivity* (Sir George Schuster); *Technical Information Services* (Dr. Alexander King). Other members of the committee include Sir Edward Appleton, Sir Claude Gibb, Mr. Hugh Weeks, Mr. Robert Hall, Mr. E. M. Nicholson and Mr. G. B. Blaker.

Unesco has 40 Members

UNESCO will meet next year at Beirut. The proposal that the next General Conference should be held there did not pass unopposed: the British delegation argued that by holding the next session away from Paris the secretariat would lose a tenth of its time and effort during a crucial year. The South Africans, on the other hand, expressed the opinion that Unesco was esteemed and understood by the Latin American countries as a result of meeting in Mexico City, and the same would apply next year to the Arab world.

New president of Unesco's Executive Board is Dr. E. R. Walker of Australia. Dr. A. Sommerfelt (Norway) and Sir Sarvapalli Radhakrishnan (India) were elected as vice-presidents in succession to M. Pierre Auger (France) and Dr. Martinez Baez (Mexico).

The conference decided that Unesco should extend its educational facilities to displaced persons. In addition negotiations are to be started with the Allied Control Authorities in Germany to determine ways in which Unesco may work in that country.

Uruguay has become a full member of Unesco and is the fortieth nation to join the organisation.

Ram-jet model achieves Supersonic Speed

IT was reported in the British press last month that an experimental model aircraft has been flown at supersonic speed. According to a report published in the *News Chronicle* of December 10, the model was propelled by a ram jet. (The ram jet, otherwise known as the 'athodyd' or 'propulsive duct', can be regarded as an extreme simplification of the gas-turbine engine, in which no compressors are required. A description of the principle of the ram jet can be found in DISCOVERY, January 1947, pp. 14-15.) This report added "it is understood that the structure of the model stood up to the stresses of bursting through the barrier of compressibility".

For security reasons the Ministry of Supply is withholding details about this advance in the realm of research and development of supersonic aircraft, and will go no further than to confirm that a ram-jet aircraft has made a successful flight.

New Comet seen in southern Hemisphere

ON the night of December 8 a brilliant comet was observed at Capetown, astronomers there describing it as the brightest since Halley's comet reappeared in 1910. The comet was later seen by astronomers in Bloemfontein, Buenos Aires, Canberra, Adelaide, Melbourne and Perth. At first it was suggested that it was Honda's comet (discovered recently by a Japanese astronomer, Minoru Honda of Tokyo), but by December 12 the International Astronomical Union was able to state that it had not been identified as one previously discovered and it could therefore reasonably be assumed to be new. Dr. D. V. Woolley, director of the Mount Stromlo Observatory at Canberra, which charted the course of the comet on several nights, said that the comet would be called 'Comet 1947-N'.

Death of Professor G. H. Hardy

THE death of one of the world's greatest pure mathematicians, Professor Godfrey Harold Hardy, occurred on December 1, the very day on which the Royal Society made its award of the Copley Medal to him. To quote the words of the Royal Society's president "it is impossible in a few sentences to describe the achievement, so varied and so abstruse, of the Copley Medallist for 1947, but in very ordinary words it may be said that Hardy saw clearly what were the most important tasks and problems lying before mathematicians; he had good judgement in selecting those which seemed ripe for attack, and he displayed the greatest skill and energy in their solution.

Born in February 7, 1877, he was educated at Winchester and Trinity College, Cambridge. He was fourth Wrangler in 1898. In 1919 he was appointed Sadleirian Professor of Geometry at Oxford, and twelve years later returned to Cambridge as Sadleirian Professor of Pure Mathematics. His books included *A Course in Pure Mathematics* and *A Mathematician's Apology*.

BINDING VOLUME VIII

OWING to the paper situation, the publishers regret that they are unable to insert the Index, Title Page and Contents to Volume VIII in each copy of DISCOVERY as in former years, but these are available free of charge on request.

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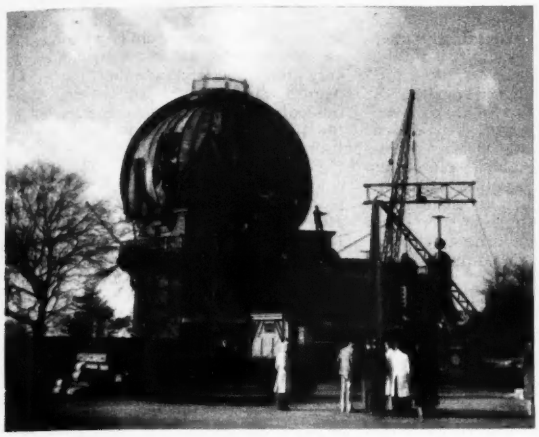
Night Sky in February

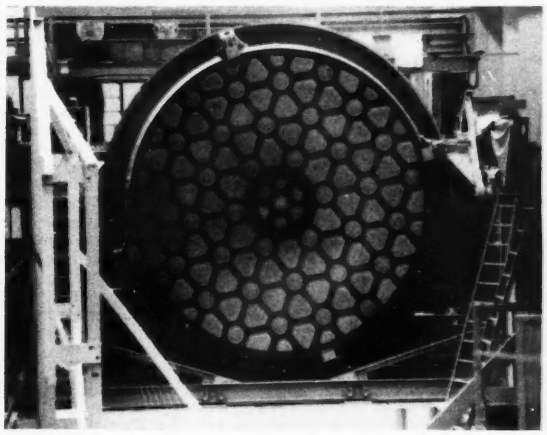
The Moon.—New moon occurs on Feb. 10d 03h 02m, U.T., and full moon on Feb. 24d 17h 16m. The following conjunctions with the moon take place:

February			
5d 06h	Jupiter in conjunction with the moon,	Jupiter	3° N.
11d 06h	Mercury ,,	Mercury	8 N.
13d 12h	Venus ,,	Venus	3 N.
23d 13h	Saturn ,,	Saturn	4 S.
24d 02h	Mars ,,	Mars	0·6 S.

The Planets.—Mercury is an evening star for more than half the month, setting at 18h 20m, and 17h 58m on Feb. 1 and 14, respectively. On Feb. 20 the planet is in inferior conjunction and then becomes a morning star, rising three-quarters of an hour before the sun at the end of the month. Venus is conspicuous in the western sky (stellar magnitude −3·5), about three-fourths of the illuminated portion of the disc being visible. The times of setting on Feb. 1, 14, and 29 are 20h, 20h 40m, and 21h 30m. Mars, in the constellation of Leo, rises in the early evening and can be seen throughout the night. The planet is in opposition on Feb. 17, that is, it is directly opposite the sun, rising about the time of sunset and setting about the time of sunrise. Notice the very close approach of Mars to the moon on Feb. 24d about 2h. Just a minute before 2 a.m. by ordinary reckoning Mars is occulted by the moon and emerges from behind the moon's disc forty-five minutes later. The occultation is due almost entirely to the moon's eastward motion amongst the stars and planets in her revolution around the earth. Jupiter does not rise until the early morning hours—4h 47m, 4h 06m, and 3h 18m, at the beginning, middle and end of the month, respectively. Notice the close approach of the planet to the moon on Feb. 5d 06h, just over 1½ hours before sunrise. Saturn is in opposition on Feb. 9, and like Mars rises in the early evening hours; it can be seen in the constellation of Leo, approaching closely to the star Eta Leonis about Feb. 22. This star is above Regulus, the brightest star in the constellation of Leo, and can be easily identified by noticing that its distance from Regulus is equivalent to the width of two fingers held at arm's length.

Amongst the interesting objects may be included the bright star Arcturus which





ASTRONOMICAL MOVING DAYS.—(Left) *The Royal Observatory transfers equipment from Greenwich to its new home at Herstmonceux Castle in Sussex. This photograph, showing the declination axis of the 28-inch refracting telescope being lifted by a crane, was taken on November 24 at Greenwich during the moving operations.*—(Right) *The 200-inch mirror has now been transported to Mount Palomar Observatory and the giant telescope will come into operation this year. Here the mirror is seen held in a frame during the long polishing process which was carried out in the optical shop of the California Institute of Technology.*

is easily found by prolonging the tail of the Great Bear. The star rises in the latitude of Greenwich at 21h 44m on Feb. 1 and 4 minutes earlier each night, so at the end of the month it rises at 19h 48m. Arcturus is so large that nearly 30,000 bodies the size of the sun would be required to equal its enormous volume.

Penicillin-resistant bacteria

ONE of the pus-forming bacteria against which penicillin has proved very effective is *Staphylococcus pyogenes*. The occurrence of penicillin-resistant strains of this staphylococcus has been known for some time. Now, according to a paper by Dr. Mary Barber published in the *British Medical Journal* (November 29, 1947, p. 863) "the incidence of strains that are grossly resistant to penicillin is clearly increasing rapidly". In the period April-November 1946 Dr. Barber found that out of 200 patients at Hammersmith hospital showing infection with this species of *Staphylococcus*, 12½% yielded penicillin-resistant strains. For the period February-June 1947, a hundred such patients included 38 infected resistant-strains. One of the conclusions Dr. Barber draws from her observations is that in any hospital using large quantities of penicillin (and today this means virtually all hospitals in Britain) resistant bacteria are probably increasing at the expense of those that are sensitive, and it seems not impossible that in time the resistant organisms will be the sole survivors.

Whether the resistance is permanent or only temporary is not discussed by Dr. Barber nor in the *British Medical Journal's* leader on her findings. (Incidentally the lay press took the lead offered by this editorial which was headed "The Waning Power of Penicillin" and published scare stories, calculated to shake public confidence in this still valuable antibiotic.) The development of penicillin-resistance is connected with the indiscriminate use of the drug in insufficiently large doses, and the *B.M.J.* editorial stresses the need to restrict the use of penicillin to cases in which the infecting bacteria have been tested and found to be penicillin-sensitive, and also the necessity of administering massive doses of the drug.

200-inch reflector at Palomar

THE 200-inch mirror for the Mount Palomar telescope is now ready for mounting. Eleven months of polishing in the optical shop of the California Institute of Technology was completed in November, and the mirror was then crated and transported to the Mount Palomar Observatory which is over 5000 feet above sea level. For the 160-mile journey from Pasadena to the mountain top many precautions had to be taken; bridges and culverts, for instance, had to be specially strengthened to take the weight of the mirror and the trailer which together amounted to over 60 tons. The mirror, which was insured for $600,000, has to be 'silvered' with a thin coat of aluminium before erection can be begun, a slow process which will take many weeks.

Social Sciences and the Future

"IT should be a platitude that the smooth running and balance of industrial communities rest upon a knowledge of the subject-matter of the social sciences," commented the Clapham Committee in their Report on the Provision for Social and Economic Research (July, 1946). But they did not go beyond stating this and similar commonly accepted generalities.

In the view of the Social Sciences Committee of the Association of Scientific Workers the Clapham Committee underestimated the urgency and importance of increasing the nation's capacity to carry out research in the social sciences and to use the results; its picture of the social sciences did scant justice to work being done outside the Universities, and the committee dealt inadequately with the relations between the producers and users of research results. For these reasons the A.Sc.W. Committee decided to make a detailed study of the subject, and the result of their labours is a lengthy document, entitled *The Furtherance of the Social Sciences*, which was presented to a conference held in London on November 22, 1947. (Copies of the document are obtainable from the A.Sc.W., 15, Half Moon St., London, W.1.)

This study is more than a review of the Clapham Report. In Section I an attempt is made to strengthen the case for expanding research in the social sciences, taking certain problems facing the British Government today—for example, distribution of manpower resources, productivity in industry, town and country planning, population, and standards of living of British colonial peoples—as concrete examples to show the useful part the social sciences can play. These examples, supported by reference to Operational Research, show how strong is the case for teamwork by scientists of many disciplines. It is pointed out that increased application to social issues is likely to enrich fundamental research.

Section II deals with the ability of the social sciences to fulfil the needs outlined. Doubts whether the social sciences can contribute to the national welfare are met by reference to present development and trends which affect their general advance.

Section III on manpower urges that expansion can proceed relatively quickly. It is agreed that there is an acute shortage of men for posts as professors and heads of research departments, but there are

qualified social scientists, suitable to fill junior teaching and research posts, holding jobs where their qualifications are not fully used.

In Section IV the case is made for the social sciences to rank high for priority in effort and resources. There is a need for social science research outside as well as inside the universities. Finally, in Section V are considered certain of the difficulties in providing for the research function in government departments.

The following recommendations, based on the above, were discussed at the Conference. (1) The formation of research teams consisting of persons trained in natural and social sciences of such branches as are required to: (*a*) examine the factual background to social problems now demanding solution, and (*b*) collaborate at the administrative level with those who devise and implement the resultant policies. (2) Research and training posts for qualified assistants should be created, having reasonable salaries and prospects. (3) To prepare qualified social scientists who have for some time been in other occupations better to fill these posts refresher courses, giving special attention to new research methods, should be organised.

(4) Steps should be taken to employ foreign social scientists resident here, and to attract others. (5) Graduates in the social sciences able to do only part-time work should be encouraged to do so. (6) Research and teaching in the social sciences should be organised in larger units, so that social scientists of the highest grade may increase their scope and effectiveness through delegation of duties of which junior grades are capable. (7) Estimates should be made now of the numbers of technical and clerical assistants who could profitably be used as recommendation (6) becomes effective. (8) In places where such reorganisation would reveal a need for equipment and buildings, estimates should be made now and passed to a central authority. (9) Encouragement and facilities should be more generally given to social scientists and others in the public service to publish findings valuable to science. (10) A Social Research Council responsible to the Lord President and comparable to the Medical and Agricultural Research Councils should be set up.

Thus, the purpose of the Conference—as Mrs. Raphael, who presided, put it—was to decide on a practical course of action.

Professor V. Gordon Childe, who introduced the Report, stated his belief that the only way to guarantee a supply of social scientists was to ensure a demand for them. At the moment there were not enough academically qualified specialists to fill all the posts needed: but if they waited until there were, there never would be.

Professor J. D. Bernal said that the object of the Report was to make the social sciences fully fledged and experimental. He regarded the first recommendation as very important, being the most immediate peg on which to hang any action. More immediate returns could be expected at the moment from the social sciences than from the natural.

He urged them to press openly for more chairs of social science, and to fill them with men keen enough to do the work. He wanted more stress to be laid on regionalisation in the social sciences. Every single area in the country should be provided with its mixed team. Social science depended on the co-operation between the observers and the observed, so that everybody concerned would take part in the survey.

In the discussion, there was much criticism of the proposed Social Research Council. Government social scientists pointed out that pressure was exerted to provide facile, short-term results. The need was expressed for a society of social scientists, a federation of societies based on the practical people, and from the body of that federation there could be representation on a Government body like the proposed Council.

The Conference accepted all recommendations, except number 10, which is to be reconsidered.

Film on Atomic Physics

THE FILM *Atomic Physics* is designed as an instructional aid in the teaching of atomic physics to students of the age group fifteen and upwards. It is not in any sense a popular treatment of the subject, and if presented at full length in an ordinary cinema it would drive the audience into the street. However, it is certain that never before on this subject has such a vast quantity of accurate information been so skilfully compressed into a single film, and scientific film societies, schools and perhaps universities will benefit accordingly.

The whole film takes almost eighty minutes, and very wisely it has been divided into five parts, each suitable for presentation separately. Atomic physics is dealt with historically, starting with Dalton in 1808 and leading up to Bikini.

The five sections are as follows:

Part I—The Atomic Theory starts with the theory as proposed by John Dalton in 1808 and outlines the progress of the 19th century, bringing in Mendeleef's Periodic Table, and ending with ideas of the size of molecules and atoms which were then current.

Part II—Rays from Atoms demonstrates how cathode rays were investigated and the electron discovered: how positive rays were found and their nature established.

Part II—The Nuclear Structure of the Atom reconstructs the early work of Becquerel and the Curies on radioactivity and shows how Lord Rutherford's work in this field led to his theory of the nuclear structure of the atom. H. G. Moseley's brilliant work in support of this theory is visually shown by animated diagrams.

Part IV—Atom Smashing: The Discovery of the Neutron. In this part the research tools of nuclear physics are described and shots of machines now used to bombard atoms are shown. The discovery of the neutron is explained and its importance driven home. The splitting of the lithium atom by Cockcroft and Walton in 1932 is discussed and a speech by Einstein explains how their work strikingly illustrated his theory of the equivalence of mass and energy.

Part V—Uranium Fission: Atomic Energy. Finally, the events of recent times leading up to the discovery of uranium fissions are brought in, and the principal facts of uranium fission explained in detail. The sequence includes a speech by Professor Frisch who was closely concerned in this work. The film now moves quickly towards its climax, explaining why it seemed possible to make an atomic bomb and showing shots of the great plants in America where this work was done; also the ruins of Hiroshima. Some idea is given of present-day research into peaceful uses of atomic energy, and this prospect is discussed by Professor Einstein and Dr. Cockcroft.

The film ends with a valuable recapitulation of what has been shown and a word about the future which promises so much if peace remains unbroken.

It was probably not necessary in Part I to go right back to Dalton's work, because the audience for whom the film is designed could be expected to know that much. But if this had not been done, the first section would have been short and unbalanced.

The general excellence of the film makes a minor point stand out as a bad passage in the script. In Part V the development of atomic energy in this country is described and there appears, almost without a break, the bald statement that the first self-sustaining pile ran in December 1942. The omission to mention at this point in the script that this major development took place in the United States was perhaps unintentional but is likely to cause annoyance in America. We are always told that science is international, but it is on just this sort of point that scientists are highly sensitive and although in the past the Americans have been criticised—sometimes with justification—for neglecting to give Britain credit for her war-time research there is no reason for our doing the same thing.

For teaching purposes it seems likely that most will be got from the film if it is used in separate sections to illustrate five lectures. There is so much in each part that teachers will probably wish to run it through, at the beginning of the lecture, explain it with the aid of blackboard or still photographs, and afterwards run through it again.

In the opinion of the reviewer, *Atomic Physics* sets a new standard for instructional films, and G.B. Instructional and all concerned with the film are to be congratulated. W. J. A.

(*"Atomic Physics" was directed by Derek Mayne, assisted by S. G. Fergusson. The first scenario was drafted by J. V. Durden, B.Sc., who was advised by Professor G. I. Finch, F.R.S. Other scientific advice was obtained from Dr. J. D. Cockcroft, Professor R. E. Peierls, and Professor O. R. Frisch and the Atomic Scientists' Association.*)

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